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THE MARCH OF SCIENCE
1931–1935

THE MARCH OF SCIENCE

A FIRST QUINQUENNIAL REVIEW 1931–1935

BY VARIOUS AUTHORS

ISSUED UNDER THE AUTHORITY
OF THE COUNCIL OF THE BRITISH ASSOCIATION
FOR THE ADVANCEMENT
OF SCIENCE

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PREFACE

THE Council of the British Association for the Advancement of Science gratefully acknowledge the collaboration of those who have contributed chapters to this volume. The genesis of the volume itself was a wish to discharge through a new channel one of the functions of the Association prescribed by its founders in 1831: "To obtain more general attention for the objects of science." It is clear that the "more general attention" is to be had for the asking: a broadening of interest in science, especially in its applications to human welfare, has been manifest in the past two decades. But it should be recalled that the elder statesmen of science who took part in founding the Association were similarly encouraged by the state of public interest at that period. William Vernon Harcourt, Canon of York and a distinguished chemist of his day, said at the inaugural meeting in 1831 that "scientific knowledge has of late years been more largely infused into the education of every class of society, and the time seems to be arrived for taking advantage of the intellectual improvement of the nation." Public interest, so far as it is able to follow science, has really never failed since the Renaissance.

Another function of this volume was also foreshadowed at the first meeting of the Association. William Whewell, then Professor of Mineralogy in the University of Cambridge, wrote that "a collection of reports concerning the present state of science, drawn up by competent persons, is on all accounts much wanted; in order that scientific students may know where to begin their labours, and in order that those who pursue one branch of science may know how to communicate with the inquirer in another." Such reports, on particular branches of investigation, have been published by the Association from time to time throughout the period of its existence, but despite these, and despite the vast increase of scientific works of reference since Whewell's time, it is hoped that the present summary volume may aid the purposes which he advocated.

The twofold object of this review, then, was defined in

the invitation to contributors in the following terms: "There is no lack of reports on the progress of any one science suited to the needs of the expert in that science. The Council seek rather to bring the progress of the sciences before (*a*) the layman, thus helping to fulfil one of the Association's prescribed objects . . .; (*b*) the scientific worker in one particular branch who may be concerned to know of progress in other branches not closely allied to his own. For a review with these objects the Council believe there is room . . ."

It may be observed that this volume, which is intended as the first of a quinquennial series, covers the first five years of the Association's second century (1931–5), though reference to earlier work is sometimes necessary in explanation of that which has been accomplished in the period under notice.

The scope of the review is necessarily restricted, especially in respect of the outer ranges of applied science; and the subjects of medicine and surgery, which have their own readily accessible literature, have not been found to lend themselves to treatment on the general lines of this review. The arrangement of sections in such a book as this must needs be arbitrary: it is made in pursuance of a sequence which begins with the universe, and continues with the structure and surface of the earth and the life upon it. In respect of man, it is concerned with the study of various influences upon him, and activities of his own in departments of science not included in these preceding categories. The concluding section presents a view of the place of science in relation to industry, and in the administration of the State. In this connexion it is not inappropriate to recall words spoken by His Majesty the King, only five years before the beginning of the period under notice, when as Prince of Wales he addressed the British Association as its President (Oxford Meeting, 1926). "This attitude of the State towards Science," he said, "makes for an easing of the paths for the advancement of Science in many directions; it marks a definite step in human progress, taken after long hesitation, but in itself new; and because it is new, we may believe with some reason that we live, not merely in an age of science, but at the beginning of it."

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THE MARCH OF SCIENCE

1931-1935

I

COSMICAL PHYSICS

By Sir James H. Jeans, D.Sc., Sc.D., LL.D., F.R.S.

THE experimental physicist, working in his laboratory, can command a very wide range of physical conditions—temperatures which range from within a minute fraction of a degree above absolute zero up to several thousands of degrees above, and pressures which range from a small fraction of a millimetre of mercury to hundreds of atmospheres.

Yet when we pass out of the Earth's atmosphere into astronomical space, we meet with far wider ranges—temperatures not merely of thousands but of millions of degrees, and pressures not of hundreds but of millions of atmospheres. Under such extreme physical conditions matter assumes properties unknown on Earth, and these properties can only be studied by pure mathematical theory. Such studies have loomed large in the astronomy of the last few years.

To understand the general nature of the problem, let us imagine that we take a journey from the surface of the sun into its deep interior. The spectroscope informs us as to the condition of matter at the surface—the pressure is, of course, low and the temperature is about 6 000° C. above absolute zero, while the atmosphere consists of atoms of the elements we know on Earth, with an immense preponderance of hydrogen, as H. N. Russell showed in 1929. Actually rather more than 90 per cent of the atoms in the Sun's atmosphere are found to be hydrogen; helium and oxygen account for about 3 per cent each; metals such as iron, magnesium, silicon, sodium, potassium, calcium for about $1\frac{1}{2}$ per cent, while, if free electrons are temporarily counted

as atoms, these account for about 1·2 per cent of the total number. Thus the metals occur in much the same proportions as in the crust of the Earth, but the gases hydrogen, helium, and oxygen occur in proportions which are very different from those we find in the earth's atmosphere. Finally the great number of free electrons—one for every eighty atoms—is something to which we can find no parallel on Earth.

Free electrons occur so plentifully because atoms are "ionized" by heat; electrons have been loosened from the atoms to which they belong and set free to travel as independent units. The higher the temperature the greater the number of electrons liberated. As the Sun's radiation necessarily flows from higher to lower temperature, it follows that as we pass from the Sun's atmosphere to its interior, the temperature must continually increase. The number of free electrons also increases, so that when we arrive at the central regions of the Sun, we shall find that almost all of the electrons have been stripped off their nuclei and travel about as independent units.

Until recently it was supposed that matter could exist only in three states—solid, liquid, and gaseous. In all these three states, the atoms exist as the indivisible units from which they take their names. But our exploration of the Sun's interior has shown that there is a fourth state, in which the atoms are almost completely broken up into their constituent particles; we may describe it as a state of "powdered atoms." And in this state the particles may be packed very closely together, so that the substance may be of very high density.

For some years stars have been known in which the greater part of the substance is packed in this very compact manner. These constitute the group of stars known as the *white dwarfs*—"dwarfs" because of their small size, and "white" because of the high temperatures of their surfaces, which correspond (although only in a restricted technical sense) to a white heat. If we compare ordinary stars to coal fires, these stars may suitably be compared to vivid electric light bulbs. The first such star to be discovered was the faint companion to Sirius. This has the high surface temperature of about 11 000° C.—nearly double that of the

Sun—but its diameter is only about a twentieth that of the Sun. This combination of whiteness and "dwarfness" results in the star giving out only about a tenth of the Sun's radiation. As most white dwarfs give out even less radiation, they are exceedingly difficult of discovery. Nevertheless, a considerable number have been identified in recent years, and it even begins to seem possible that they may be the commonest type of stars in space. The most recent addition to their number, discovered by G. T. Kuiper in 1935, is of special interest as being the smallest star so far known. Its radius is only a two-hundredth part of that of the Sun, or half that of the Earth, so that its cubic content is about an eight-millionth part of that of the Sun. Yet it probably contains nearly three times as much substance as the Sun, so that its density must be of the order of 36 million times that of water, a cubic inch of its substance weighing 550 tons, so that a pinhead of it would break a man's back. This star has the high surface temperature of about 28 000° C, which is about five times that of the Sun. Each square inch of the Sun emits about 50 h.p. of energy, but the corresponding figure for this star is about 30 000 h.p.—enough to run a big liner. Yet, because of its small size, the star gives out less than a thousandth part of the Sun's radiation.

R. H. Fowler has studied the final end to which such a star would approach as it continually lost energy by radiation, and finds that its electrons and nuclei would finally fall together so as to form one huge molecule. He describes such a star as a *black dwarf*—"dwarf" because it is still of minute size, and "black" because it no longer emits any radiation at all. In such a star, as Chandrasekhar and others have pointed out, the ionization is produced by the pressure rather than the temperature—the atoms are not so much broken up by heat, as crushed into pieces by extreme pressure, and there proves to be quite a simple relation between the radius and the mass of a perfectly cold star of this kind. When the mass is small, the radius is of course small also. Increasing the mass naturally increases the radius—at least for a time. But each increase of mass also increases the internal pressure, and the density with it, so that a time comes when this increase of density takes charge of the whole increase of mass, without calling for any

increase in size. After this, a further increase of mass will actually *reduce* the size of the star, until finally we find that a star whose mass was infinite would be infinitesimal in size. Thus there is a maximum of size which no black dwarf can exceed.

In 1935, D. S. Kothari and R. C. Magendar, of the University of Delhi, calculated the sizes corresponding to various different masses. The radii they calculate for ordinary white dwarf stars, such as the famous Sirius B, prove to be somewhat less than those actually observed, but this is not surprising or disconcerting, since the actual stars are very hot, while the idealized black dwarfs which figure in the calculations are supposed to be completely cold. They next consider black dwarfs of far smaller masses, equal only to those of Jupiter and Saturn, and find that such stars would have radii comparable with, although again somewhat smaller than, those of these planets. Finally black dwarfs, having the masses of Venus and the Earth, would have almost precisely the actual radii of Venus and the Earth. This has led them to suggest that the physical constitution of the planets may be merely that of black dwarf stars having masses which are only a few millionths of the masses of ordinary stars. If they are right, the nearest dwarf stars are very near home indeed, and through their studies of the depths of space and explorations in the very heart of modern theoretical physics, the physicists have stumbled upon the solution of a very old problem and one very near home—the structure of the interiors of the Earth and the other planets. These would consist of matter in its fourth state, in which the nuclei of the atoms are held together as in one single huge molecule, while the electrons described ordinary orbits. For example, the interior of the Earth would be a single molecule formed out of millions of millions of atoms of iron, silicon, sodium, and so forth—the "substance" of the greatest known molecular weight. It remains to be seen whether such a view of the Earth's interior can be reconciled with the findings of seismology.

The white dwarfs have figured prominently in other parts of the astronomical picture also. The nature of the planetary nebulae has long been a mystery. In the telescope these objects appear as nebulous patches of fairly regular shape,

often elliptical or nearly circular, but always with a bright and excessively hot star at their centre. It now seems clear that these central stars are merely white dwarfs at excessively high temperatures. Van Maanen and Anderson find that the average central star has a temperature of about 24 000°, which means that its surface emits about 250 times as much radiation per square inch as the Sun. It is nevertheless only about ten times as luminous as the Sun, so that its radius can only be about a fifth of that of the Sun. Clearly, then, these central stars are of the nature of white dwarfs. The remainder of the nebula consists of a vast atmosphere, which is raised to incandescence by the radiation from the hot central star, its dimensions being of the order of 20 million times that of the Sun, or 100 000 times that of the Earth's orbit. The smallest of known stars, as we have just seen, is a white dwarf with a radius only a two hundredth that of the Sun. These other white dwarfs, with their vast encircling atmospheres, are certainly the largest of known stars.

Large though these planetary nebulæ are, they are quite insignificant compared with the great "extra-galactic" nebulæ which lie right outside our own system of stars. These also have been the object of much study in recent years. In a general way they are shaped like the galactic system, but for a long time astronomers refused to admit that they could be at all comparable with it in size, or of the same general nature. The researches of Hubble have done much to establish identity of Nature, for he has discovered Cepheid and other variable stars in the nebulæ similar to those we observe in our own galaxy, and more recently novae and globular clusters also. Until the last few years, however, it seemed necessary to admit that the nebulæ were quite inferior in size to our own galaxy. The diameter of our galaxy was thought to be about 300 000 light-years, while that of the Andromeda nebula could be measured as only about 30 000 light-years, and other nebular diameters were thought to be still smaller. The question of the diameter of the galaxy has recently been re-opened by Trumpler and others, and now it seems likely that it may be well below the 300 000 light-years just mentioned—possibly as little as 100 000 light-years. At the same time Shapley has shown

that the nebulæ extend far beyond the limits suggested by their images on photographic plates, the diameter of the Andromeda nebula being certainly as much as 60 000 light-years, and possibly more. Thus the supposed difference in size is reduced to insignificance, and it is much the same with a supposed difference in mass. The galaxy is believed to have the mass of from 100 000 to 200 000 million suns, whereas early estimates by Hubble assigned masses of only about 1 000 million suns to the nebula. Recent studies by Sinclair-Smith raise this last figure to about 200 000 million. Thus the nebulæ now seem to be very similar to our own galaxy, in size and mass as well as in content, except perhaps that they are in varying stages of development.

Of recent years, a good deal of study has been given to the arrangement of these nebulæ in space. A preliminary discussion by Hubble in 1926 had seemed to suggest that they were scattered fairly evenly through the different regions of space, but further study has revealed marked departures from uniformity. For instance, J. H. Reynolds has found that the majority of the nearest nebulæ of all, those up to about 2 300 000 light-years distance, lie to the south of the Milky Way, while for distances between this and 13 000 000 light-years the preponderance passes to the north.

A question of very great interest is whether the distribution of nebulæ shows any steady continuous change as we pass to very great distances. If space were Euclidean or "flat," then the volume of space within any assigned distance of the Earth would be proportional to the cube of this distance—on going twice as far out into space, eight times as much space would come within our purview. Clearly, then, if the nebulæ were uniformly distributed throughout a space of this kind, we ought to find that on going twice as far into space, the number of nebulæ would increase eight-fold. But space need not be of this kind, and actually the theory of relativity suggests that it is not flat, but is endowed with a "positive" curvature, somewhat like the curvature of the surface of the Earth. If this is so, then the volume of space which lies within an assigned distance of the Earth is not proportional to the cube of the distance; there is a falling-off at great distances, so that when we go twice as far into space, the volume of space increases somewhat

less than eightfold. If the nebulæ were uniformly distributed through such a space, we should expect to find a similar falling off in the number of nebulæ. Hubble and his collaborators are engaged in looking for such a falling off, but the preliminary results they obtained in 1935 are the exact opposite of those anticipated; the nebular numbers seem to increase *more* rapidly than the cube of the distances, so that on going twice as far into space, the number of nebulæ is increased by something more than eightfold. It ought to be said at once that the observed excess is not very marked—it may quite possibly be a mere local increase, which would disappear on going still farther out into space. But also it may quite possibly be real, in which case two explanations are possible. The first is that our own galaxy may be situated in a region of space which is abnormally deficient in the number of galaxies it contains; in brief, we live in a comparatively empty region of space. The second is that space may not be endowed with a "positive" curvature at all, as Einstein originally supposed, but with a "negative" curvature, so that when we go twice as far out into space, the volume of space is increased *more* than eightfold. In this latter event space would not be finite, but would extend to infinity in all directions. Much more observation is necessary before we can decide between these various alternatives. It may be added that considerations of an entirely different nature have recently led Einstein to entertain the possibility that space may not be endowed with any curvature at all, either positive or negative. In this case also, space would extend to infinity.

That the more distant of these extra-galactic nebulæ are receding from us has long been known. Recently, it has been found that if the proper allowance is made for the motion of the Sun in our own galaxy, then all nebulæ, both distant and near, are receding—not, it is true, from us, but from the centre of the galaxy. Further, they are found to be receding with speeds which are approximately proportional to their distances, the speed being roughly a hundred miles a second for every million light-years of distance. Thus the furthest known cluster of nebulæ, at distances of about 240 million light-years, are receding at about 25 000 miles a second. The highest speed so far observed for an

individual nebula is 26 000 miles a second, which is a seventh of the velocity of light, or, in perhaps more intelligible language, two million times the speed of an express train. Doubts have sometimes been expressed as to whether such high speeds can be real, but there would seem to be little justification for this, since the law of motion being proportional to distance was first predicted by the theory of relativity, and only subsequently was confirmed by observation.

In the original relativity theory of Einstein, space was supposed to be curved, so that it bent back upon itself to form a volume of finite dimensions. It was also supposed to be static, so that its dimensions remained always the same. Some years later, Friedmann and Lemaître showed that a space of this kind could not be static; if it existed momentarily, it would be in unstable equilibrium, and would inevitably start either to expand or contract within a very short time. Recent mathematical discussions by Einstein, de Sitter, and others have now shown that three alternatives are physically possible—

(1) Space may have started in the way Einstein imagined, and have been expanding ever since. If so, the present rate of expansion shows that the motion must have been in progress for some thousands of millions of years.

(2) Space may have started of almost any size we please, contracted to a minimum and expanded ever since. If so, the epoch of minimum dimensions must have occurred some thousands of millions of years ago.

(3) Space may have experienced regular alternate expansions and contractions in the past. If so, it will continue to do so in the future, and no limits can be assigned to the past age of space.

These three possibilities have an obvious bearing on the question of the age of the universe. The arrangement and motions of the stars show certain statistical properties which have suggested to many astronomers that stellar ages are to be reckoned, not in mere thousands of millions of years, but rather in millions of millions of years. If so, the first of the three above alternatives must be excluded as giving nothing like time enough for stellar evolution, and as the second seems highly improbable, we are practically limited to the third. On the other hand, the age of the Earth

is known, from the composition of its radioactive rocks, to be of the order of only two or three thousand million years. Other lines of evidence suggest that this is also the age of the solar system as a whole. Again, the radioactive composition of meteorites, some of which probably come from far outside the solar system, indicate a similar age, while the general structure of the galaxy and of its moving star clusters in particular seem to limit the age of the whole galaxy to a somewhat similar figure. All these figures appear to throw doubt on the estimated stellar ages of millions of millions of years. Although the question must still be regarded as open, probably the majority of astronomers now favour an age for the whole universe of only a few thousands of millions of years. Such an age is consistent with any one of the three alternatives mentioned above, and of these the first would seem to be the most probable.

On the supposition that the first is the true alternative, Eddington has recently calculated that initial unexpanded space must have had a radius of the order of 1 100 million light-years; the radius may perhaps be about eight or ten times as great by now. If we construct a model of space on the scale of two million light-years to an inch, the initial circumference of space would be about 100 yards; this may have expanded by now to about half a mile. In such a model the farthest visible nebulæ are only some ten feet from the Earth, while our whole galaxy is of the size of an average pinhead—perhaps $\frac{1}{10}$ inch in diameter. The stars which are visible to our unaided eyes are all contained in a sphere of about $\frac{1}{600}$ inch radius—a mere speck of dust.

Finally, on the same scale, the Sun is a single electron, and if the electron were not indivisible, our Earth might be represented by a millionth part of an electron.

II

GEOLOGY

By Professor P. G. H. Boswell, O.B.E., D.Sc., F.R.S.

GEOLOGY is so wide in its scope that it makes close contact with many other sciences. Since its ultimate aim is to trace the sequence of events in and on the Earth's crust, its methods must be chiefly historical, but although the geological record is known to be incomplete, the main trends are well understood and therefore we do not expect that advances in knowledge will be sensational. And so, when we record that during the past five or ten years no new principles have been established and no major modifications of old ones have been necessary, we bear witness to the soundness of the foundations of our science. The exploration of new territory, the detailed re-investigation of ground hitherto known only by reconnaissance or made necessary by the general advance of knowledge, and the patient accumulation of facts relating to the composition and contents of rocks are a pre-requisite of the brilliant generalizations which usually arise only at long intervals.

The application of science to human affairs need not and does not wait upon the establishment of new principles; more often it is based upon the interim results of observation and experiment. To those who are not specialists in the subject, applied geology inevitably arouses greater interest than details of minerals or fossils, essential though they be to the progress of the science and its applications.

In this section, therefore, it is proposed to select for consideration some of the more interesting developments or trends in geology, the purport of which can be understood by those who have no more than a general acquaintance with science. The subjects touched upon may thus be grouped—

(1) The distribution of metalliferous ores and other minerals; modern methods of locating them and of determining underground structures and the presence of water; silicosis and similar diseases incurred in exploitation and utilization of mineral materials; recent work on the constitution of coal; the distribution of the rare elements.

(2) Recent work on sedimentary rocks, including the X-ray analysis of clays; the trend of investigation of igneous rocks and equilibrium-relations of their constituent compounds; the use of petrofabric analysis in research on metamorphic rocks.

(3) Additions to knowledge of the earliest forms of life and of the range in time of plants and certain animals; the relation of early human cultures to the Ice Age and the phases of late geological history; the estimate of geological time by the recording of annual layers of sediment and their correlation over the Earth's surface.

The part played by various mineral substances in national economy, the geographical distribution of mineral occurrences and its bearing on the question of possible *mineral sanctions*, have been discussed by Sir Thomas Holland in an important series of publications, of which the first was his Presidential Address to the British Association in 1929. No nation is self-contained in the matter of war-supplies of minerals, and these cannot be made artificially or replaced by substitutes. Industrialized countries have been well explored by geologists and significant new discoveries are therefore unlikely. Sir Thomas Holland's thesis is that by an agreement to add a separate and supplementary Mineral Sanction to Article XVI of the League of Nations Covenant, the outbreak of war could be checked by the threat of withholding supplies of essential mineral materials such as iron, oil, copper, tungsten, nickel, chromium, aluminium, antimony, lead, zinc, and many others. Even a mineral-rich country such as the United States of America lacks antimony, chromium, manganese, nickel, and tin. Although the British Empire—most self-supporting but disperse—needs as a whole only antimony, oil, mercury, and sulphur, the isolation of Great Britain would make many shortages embarrassing.

The discovery and exploitation of metallic ores and oil have been greatly assisted in recent years by improvements in geophysical prospecting. The methods of exploration fall into five categories: electrical, magnetic, gravity, seismic, and radio-active. Of these, the most notable progress has been in electrical and seismic methods; and, in the case of the former, in the practice known as "electric coring," which

depends on the variable resistivity of rocks to the passage of electricity. The procedure in resistivity methods of electrical exploration can be briefly stated as follows. As is well known, materials such as metals, ores, rocks, fresh water, and salt water conduct electricity with varying facility. Resistivity is the converse of conductivity. When a known electric current is made to pass into and through the Earth's crust and the consequent potential gradient is recorded, the variation in resistivity of the rocks can be determined and the changes in the character of the transmitting medium or the situation of surfaces of discontinuity can be estimated. By these methods we can locate partings between beds of different character, surfaces of buried landscapes, or of salt water or fresh water impregnating rocks, or even the depth (and to some extent the character) of the bed of a stream or the firm ground of swamps. The recording of resistivity can be made also in a vertical direction in an uncased borehole by the introduction of two poles at fixed distances apart. As these are drawn up the hole in the mud, like a string of drilling-tools, the variations in the resistivity of the rocks passed through can be recorded by the fluctuation in the transmitted current. As the resistivity of rocks is largely affected by their contained fluids, the difference between sand containing oil (a non-conductor) and sand containing salt water is clearly shown. Also, it is a well-known fact that water of varying salinity creates a potential difference when passing through a capillary. By measuring this potential difference a record is obtained of the permeability of the rocks. Thus the resistivity and permeability can be measured throughout the borehole, which may be as much as 8 000 feet or more in length.

The other geophysical method which has been developed extensively in recent years is the seismic, in which an artificial earthquake is produced by explosives at a small depth, and the time or arrival of the shock at various points determined. In this way a clue is afforded to the character of the rocks present in the Earth's crust, for different rocks vary in their elasticity and transmit waves of disturbance at different velocities. By this method, also, underground surfaces of discontinuity can be located. A simple application of the method was that of ascertaining the thickness of

the Greenland ice-cap, by obtaining "echoes" of soundings reflected from the floor of solid rock.

A promising field is opened up by investigations of the varying resistivity of rocks when dry, and when sodden with fresh or salt water. The determination of underground water-levels and of the degree of freshness or hardness of the water is clearly of great economic importance, not merely in mining and engineering undertakings, where water is a bad master, but from the viewpoint of the recovery of potable water supplies, the increasing demand for which recently has not only stimulated geologists and engineers, but has also galvanized politicians.

Considerable advances in knowledge of the propagation of earthquake-waves are being made, but this branch of the subject now falls within the domain of physics rather than of geology. It has, nevertheless, important geological bearings.

Reverting to the subject of mining activities necessitated by the increasingly rapid consumption of ores and useful metals, we cannot but welcome the reopening of the question of the cause of silicosis (or miners' phthisis), which takes a serious toll of human life. The disease was formerly regarded as the result of the inhalation of air laden with dust consisting of finely divided silica (for example, quartz or flint) produced by blasting or grinding. A similar disease, asbestosis, has been attributed to the effect on the lungs of tiny fibres of the mineral asbestos. By challenging the generally accepted view of the cause of silicosis, and attributing the disease in large part to another widespread mineral, sericite (one of the micas), Dr. W. R. Jones has, by comparing it closely with asbestosis, stimulated discussion and given an impetus to related research in the field of pathology as well as in geology and mining. The disease has a high incidence, Dr. Jones observes, in mining fields where silica-rocks are rare or absent, but where sericite is abundant; dusts in mines, potteries and other works using mineral materials are often deficient in free silica, but rich in fibrous sericite. The same is true of the mineral substances extracted from silicotic lungs. Recent investigations have revealed the wide extent of silicosis in certain colliery districts, foundries, and potteries, with the result that Government committees are now

actively engaged on inquiries and experiments in Britain, Germany, and the United States of America.

The highly detailed chemical and spectroscopic analyses of minerals and rocks which are slowly becoming available serve to show how widespread and numerous in common rocks, and indeed concentrated in sediments, are certain of the rare elements. Among the more noteworthy occurrences are those of gallium, scandium, germanium, selenium, lithium, caesium, and rubidium in varying proportions in bauxites, iron ores, coals, clays, shales, and deep-sea sediments. It is not surprising to find that many of these elements are present also in minute quantities in living animals and plants—where they are doubtless derived from the soil. Thus a clue is afforded to the source of the rare elements in, for example, coal—a rock in places relatively rich in certain elements such as arsenic, beryllium, boron, germanium, molybdenum, nickel, vanadium, and ziconium, although their relative and varying abundance is difficult to explain. As Professor V. M. Goldschmidt points out, the presence of these constituents may be an important factor in determining the suitability of different coals for use as pulverized fuel or for distillation to yield oils, because of the part they may play as catalysts, that is, substances which promote particular chemical reactions while remaining themselves unchanged. The relative proportions of the rare elements differ in the various constituents, next to be considered, which go to form coal.

It is now some eighteen years since Dr. Marie Stopes first focused attention on the composite nature of common coal, and gave names to the several constituents which may be distinguished by inspection even in hand-specimens; the glassy looking vitrain; the bright but not perfectly homogeneous clarain; the hard dull durain; and the sooty fibrous mineral-charcoal or fusain. More recent microscopic study of these constituents by Dr. Marie Stopes and Professor H. G. A. Hickling in this country and by other workers abroad, have confirmed their distinctness and shown the nature of the materials—wood, bark, spores, resins, waxes, etc.—which enter into the composition of each. These investigations are being actively supplemented by chemical studies of the components, and already it is being

found worth while for special industrial purposes to effect a separation of certain constituents of the coal before use.

The main trends of research in petrology will be considered in relation to the three principal groups of rocks, namely, the igneous rocks (those that have solidified from the molten state), the sedimentary rocks, and the metamorphic rocks.

About a quarter of a century ago Dr. Alfred Harker recognized, though with wise caution, the evidence of "hybridism" in igneous rocks. Shortly afterwards, Professor R. A. Daly proposed his intriguing hypothesis of magmetic stoping and depth assimilation (that is, the breaking-up and incorporation by the rising magma of the rocks forming its roof and walls). Daly thus postulated the reality of hybrid or "mixed" magmas and their rock-products on a large scale. Although the idea attracted world-wide notice, its implications were at first resisted by conservative petrologists, who were prepared to admit "contamination," but discounted its scale, despite much indirect corroboration even then on record, notably in the observations of the French school.

As a stimulus to actual research, Daly's hypothesis had little influence until it was floodlit by Dr. N. L. Bowen's "reaction principle in petrogenesis"—a far-reaching principle which explained certain mineral-transformations whereby a crystal tends to adjust its composition, during growth, to changing conditions in its surrounding liquid magma. The corollary to this reaction-principle is the doctrine of crystallization-differentiation, which—as first enunciated—appeared to provide a satisfactory explanation not only for igneous rock variation but also for the world-wide distribution of the same comparatively few standard rock-types.

Inevitably, there followed a period characterized by quietly persistent work which might be described as an impartial re-examination in detail of igneous masses already "known," but to be reconsidered in the light of the two apparently opposed doctrines. Initial results had the effect of reconciling the two schools. While systematic description of rocks and the scrupulously careful mapping of field-facts lost none of their fundamental value, each of these lines of research has claimed its own group of workers, with illuminating results.

A revival of interest is to be noted in the study of sedimentary rocks, that is, those laid down on the beds of rivers, lakes and seas, or forming soils and wind, rain, or ice-drifted deposits on land. University laboratories have been specially built and equipped for the study of sedimentation, including the sizing and shaping of coarse particles, the effects of currents, compaction, and other phenomena; and a new periodical, the *Journal of Sedimentary Petrology,* has been founded. Sediments in process of formation at the present day in the northern Pacific, the northern and southern Atlantic, the West Indies and the North Sea, as well as in lakes and in the deeper parts of the oceans, are being investigated in order that light may be thrown on those more ancient deposits which serve to document the Earth's history.

Although the coarser sediments, such as gravels and sands, are often made up of fragments which are themselves composite, the finer sediments usually consist of fragments of individual minerals, the finest material of all being lumped under the general term clay. It is in the investigation of clays that the greatest progress has been made in recent years—a direct result of the utilization of a new weapon furnished by the physicist, namely X-ray spectrography. The investigation of well-crystallized minerals by means of beams of X-rays has proceeded rapidly, but the less amenable fine-grained clays still offer a wide field for exploration. So rapid has been the progress of the study of the mineralogical composition of clays during the past five years that a complete revision of our ideas of the relationship of various clays to one another, and the part they play in soil phenomena, has become necessary.

The simplest group of clay-minerals is named, after its best-known member, the kaolinite group. Kaolinite itself forms the basis of kaolin or china clay, well known in industry. The mineral is formed from the decomposition of more complex minerals under either atmospheric weathering of the action of hot gases and solutions at a late stage of intrusion of igneous rocks such as granite. The four members now known in the kaolinite group, namely, kaolinite, dickite, nacrite, and metahalloysite, have the same chemical composition, $Al_2O_3 . 2SiO_2 . 2H_2O$, but they can be distinguished

one from another by physical characteristics, such as their dehydration temperatures, and by differences in the arrangement of their atoms as revealed by X-ray analysis.

Another group of clays, of which bentonite and fullers' earth are typical, contains predominantly the clay-mineral montmorillonite, a hydrated silicate of aluminium and magnesium. It is noteworthy that the clay-base of many soils is largely composed of montmorillonite (and to a less extent of a related mineral, beidellite), a fact which suggests that it is a characteristic product of the decomposition of suitable rocks and complex minerals under terrestrial and fresh-water conditions. Indeed, bentonite is supposed to result from the alteration in water of a volcanic ash.

An important property of some of these clay-minerals (but not of the kaolinite group), from the industrial as well as the scientific standpoint, is their capacity for base-exchange, that is, their power to take up atoms of certain elements in place of others, thus forming new compounds, as in the process of water-softening, where sodium is made to replace calcium. Again, X-ray analysis has thrown much light on this phenomenon, and has revealed a sheet arrangement of constituents (the silica [SiO_2] sheet, the gibbsite [$Al_2(OH)_6$] sheet, the brucite [$Mg_2(OH)_6$] sheet, and so on). This layer structure explains the micaceous habit and marked cleavability of clay-minerals.

The few marine clays which have been the subject of detailed work up to the present time have a clay-base of much more complex character. Instead of being simple hydrated silicates of alumina like the kaolinite group, they appear to contain significant amounts of the alkalies potash and soda, as well as lime, magnesia, and iron. The exact manner of their formation is at present under investigation.

An interesting example of the application of petrological technique to coarse deposits is the method developed by Dr. F. Zeuner in studying river gravels. It is based on a statistical comparison of the petrographical "make-ups" of certain standard grades of gravel. It enables the investigator to deduce from the decrease or increase of certain components with decreasing grain-size the climatic conditions under which the gravels were deposited. The leading idea is that in gravels which were deposited under humid conditions,

the silicate rock-components were partly decomposed by the atmosphere and therefore rapidly destroyed by the mechanical action of the river. In gravels deposited under arid conditions, the silicate rock-components retain their hardness and resist the abrading action better, and the analysis shows a different aspect.

The method is particularly useful for river-terraces of Tertiary and Pleistocene age, since it makes possible the recognition of climatic fluctuations. Terrace deposits accumulated merely as a consequence of climatic changes may be distinguished from those formed by alterations of the base-level. The procedure also permits the detailed study, among other points, of alterations in the catchment area of rivers. Further, unaltered gravels can be distinguished from those decomposed by subsequent weathering. The applicability of the gravel-analysis or *Schotteranalyse* depends to a certain degree on the bulk composition of the gravels, the results being best in areas with gravels rich in varied components.

Notable advances in petrotectonics or petrofabrics have been made since B. Sander and W. Schmidt introduced the technique in their study of metamorphic rocks. The major deformations of rocks are a summation of the partial deformations of the units constituting the rock-masses. Statistical study of the lattice-arrangement or form-arrangement of the units, which are mostly grains of minerals such as quartz, calcite, mica, etc., of deformed rocks, provides a pattern of the fabric. This pattern is related to the strain-ellipsoid in a definite fashion, so that its investigation provides evidence concerning the directions of the deforming forces. Thus the study is of importance in broader tectonic investigations; it has been employed, for example, in the Eastern Alps, and the results suggest that certain modifications of the theory of overthrust sheets or nappes in that region may be required. The stress at any one time leaves its characteristic imprint not only on the features of the hand-specimens, such as foliation and cleavage, but also on the crystallographic orientations of the constituent minerals. Repeated deformations at different times in geological history may or may not be due to stresses differing in direction and intensity; the final deformation at times obliterates field-

evidence, at least, of earlier ones. The method has shown that in many rocks traces of earlier deformation may be found, although only the later one is visible in hand-specimens. The development of petrofabric analysis thus opens up a wide field of investigation in the metamorphic rocks as a whole.

Geological research has in recent times thrown little or no new light on the origin of life on the Earth. We are still faced by the problem of the sudden appearance, in the oldest Cambrian rocks, of representatives of many of the present-day forms of life. A few years ago, however, the record was carried farther back by the finding of an impression of a crustacean-like organism (*Xenusion*) in a boulder of quartz-sandstone resembling the Dala sandstone (of upper Pre-Cambrian or Algonkian age) of southern Sweden. Unfortunately, the fossil was not found in place, but was contained in a glacial erratic in boulder clay at the Heiligen Quarry, Mark Brandenburg, in Germany. There is an element of uncertainty also regarding the claims of the late Sir T. Edgeworth David of the discovery of a rich Pre-Cambrian fauna, apparently with arthropod affinities, in Australia; they have not been generally admitted because of the uncertainty regarding the organic origin of the impressions. Much interest attaches, however, to the discovery of what appear to be algae, and also horny brachiopods, in the upper Pre-Cambrian (Beltian) of the United States of America.

The systematic study of fossils and the relationship of the various members of groups to one another, together with the detailed investigation of strata in many parts of the world, proceeds almost as a matter of routine. Any attempt to cite the results would occupy much space, and would perhaps be unacceptable to the non-specialist reader. But it may be emphasized that on this study output of facts and their co-ordination depend the elucidation of the history of life on the Earth, the trends of evolution, the unravelling of rock-structures and the economic exploitation of many of the mineral resources contained in the Earth's crust. One of the most outstanding facts relating to the history of life is the recent discovery that land-plants are more ancient than has hitherto been thought.* Remains of such plants

* See, further, the section on Botany.

(*Psilophytales*) have long been known from the Lower Old Red Sandstone (Devonian); they have been stated to occur in the preceding system, the Silurian. Recently they have been found on the same slab with Lower Wenlock graptolites in Victoria, Australia. The steady continuance of work on fossil plants has resulted in the more exact definitions of floras in the Coal Measures and has assisted the correlation of coal-seams in different areas: it has also been related to the investigation of the fresh-water molluscan faunas to be referred to later. Interest has also been recently aroused by work on the origin of the present-day floras of Britain and other lands and their history before and during the Glacial Period.

Although considerable advances in knowledge of many groups of fossil organisms have been made, two only can be selected, as examples, for mention here. The work of Mr. W. S. Bisat, announced about ten years ago, on the succession of species and mutations of goniatites (which belong to the class that includes the ammonites, belemnites, and cuttlefish) in the carboniferous rocks, has proved an active stimulant to investigations in many areas and has assisted in the elucidation of the structures and correlation of the carboniferous rocks, which include coal seams. In like manner, the study of the distribution of the fresh-water mussels, also belonging to the mollusca, has proved of considerable economic value, as a result of investigations by Professor A. E. Trueman and others. By collecting large numbers of these fresh-water shells and noting the association of particular species with different coal-seams, geologists have been able to throw light on the relative ages of coal-measures throughout Britain, and even throughout wider areas (a problem which had hitherto defied satisfactory solution).

Investigations of the rocks at the top of the geological column, namely the Pleistocene and Recent formations, have furnished results which are probably of greatest interest to the layman. The discoveries of the remains of early man properly find a place in the story of archæological progress, but the determination of the age of the human remains and the contemporary environments is the task of the geologist. The active labours of archæologists in many lands have added enormously to knowledge of man's ancestors, and the

relations of early human cultures to the successive ice-advances of the Glacial Period and to the intervening milder phases now bids fair to be established with certainty.

The most ancient remains of man, those of Eoanthropus (Piltdown, Sussex), Pithecanthropus (Java), Heidelberg Man (Germany), and Sinanthropus (Pekin) appear to be roughly contemporaneous and to belong to the Older Pleistocene. Their relation to the Great Ice Age is still uncertain, for they are not associated with glacial deposits. The late Mr. W. D. Matthews's principle seems to apply to early man, namely, that if a race of animals evolves at a single centre, a succession of waves of increasingly advanced genera must radiate from that centre, the latest and highest types being found at the centre and the lowest at the outer limit. Controversy still continues as to whether the centre of dispersal was Asia or Africa, with the balance in favour of Asia. The claims that men of modern (*Homo sapiens*) type, in contradistinction to the primitive types enumerated above, already existed in Early Pleistocene times cannot be regarded as substantiated, for the skeleton at Oldoway (Tanganyika) has proved to be a later burial, and the jaw from Kanam and the skulls from Kanjera (Kenya) are in the present state of knowledge of doubtful provenance and age.*

The relations of the cultures of early man, as shown by the occurrence of stone industries, to the various phases of the Glacial Period has still to be established in many regions. In the British area, which lay at the margin of the oscillating ice-sheets, pre-Abbevillian (pre-Chellian) man appears to have flourished in eastern England before the advent of the first great ice-advance. During the first interglacial epoch, Abbevillian man was in occupation of northern France and possibly of southern England, at that time united with the Continent. The fabricators of the earliest Clactonian flake industry appear also to have lived in eastern England. The second ice-advance must have been contemporaneous with early Acheulian industries farther south, for Middle Acheulian man seems to have followed up the retreat of the ice in East Anglia. In the mild (second) interglacial period, late Acheulian man left evidence of his craftmanship, apparently contemporaneous with the cultures of late Clactonian

* See, further, the later section on Anthropology.

and Early Levalloissian types ("Mousterian"). The last-named industries were those associated with the skeletons of Neanderthal man in Europe and Asia, but no such skeletal remains have yet been found in Britain. The third ice-advance probably coincided with the cold "Mousterian" epoch of the Continent, and the succeeding third interglacial with the advent of modern man of the Cro-Magnon (Aurignacian) type. The fourth ice-advance in the east of England may possibly correspond to the cold phase which Magdalenian man seems to have encountered in more southern countries.

The correlation of these human culture-stages with the glacial and interglacial episodes of other European countries is not yet agreed upon. Similarly, although progress has been made in establishing the relationship of the cultures to the rainy and dry periods in Palestine and India, and in Africa from Egypt to the Cape, reliable comparison with European phenomena has still to be effected.

The reluctance of geologists to record Earth-history in terms of years is well known; indeed, the opportunities available for measurement are few. Therefore geologists have welcomed the assistance of physicists, who, by investigating the relative proportions of radio-active elements, such as thorium or uranium, and their decomposition products, in minerals obtained from rocks of varying geological ages, have been able to interpret those ages in years. Thus, the age of the oldest rocks of the Earth's crust has been computed at some 1 800–2 000 million years. Only in the case of the most recent rocks, however, has the historical method of measuring time in years been applied directly to geological chronology. The most fruitful line of research was inaugurated by Baron Gerard de Geer when he measured the time that elapsed during the retreat of the Swedish glaciers in the closing stages of the Ice Age. In the lake-like areas of water left by the retreating ice were deposited layers of sediment (varves), each beginning as a coarse, sandy band below and passing upwards into fine clay. The coarse material was regarded as the result of the active transport of sand due to the summer melting; and the clay as having settled from the water slowly during the winter. By plotting in graphical form the thicknesses of successive varves,

de Geer was able to connect the upper layers of one series with the lower layers of another nearer to the ice front, and thus to obtain a cumulative series which showed that some 12 000 years have elapsed since the retreat of the ice from the coast of southern Sweden. The investigation was then extended to older stages of glaciation in Denmark and northern Germany and, in his recent publications, the distinguished glaciologist claims to be able to recognize similarities in the succession of varve-thicknesses in Sweden to those in more distant European countries, in Siberia, North America, Patagonia, East Africa, and New Zealand. Hence he regards the seasonal variations as expressions of world-wide changes, and moreover believes that the records provide evidence also of biennial variation of solar radiation (possibly due to cosmic dust). He therefore considers that it is possible to establish the *teleconnexion* of varves.

Even by taking account of earlier resting-stages in the retreat of the ice, we cannot trace the record back farther than about 16 000 years—to the glaciation of Denmark, northern Germany and Poland. On these lines, the estimates of the duration of the Ice Age and of the history of man on the earth vary from 200 000 years to 500 000 years.

As a confirmation of the validity of the method, it is interesting to note that the graphs of the silt-varves of late geological times have been correlated by Dr. R. Lidén with the annual rings of the giant firs (sequoias) of the Western States, which according to Professor Douglass date back 3000 years and can be linked with early human occupations; further, the Baroness Ebba de Geer has correlated some of these varves and sequoia records with the rings of old logs found in ancient water-forts in Sweden, constructed during the period A.D. 320–580.

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III

GEOGRAPHY

By G. R. Crone, M.A.

GEOGRAPHY in its literal meaning is the study of the Earth and of the phenomena upon its surface. In contradistinction to history, which is concerned to answer the questions "When" and "Why then," it seeks to find answers to the questions "Where" and "Why there." Originally, geography was mainly descriptive, but it now justifies its claim to be regarded as a science by substituting explanation for description: that is, while continuing in the first instance to collect details of the distribution of all the phenomena on the Earth's surface, it proceeds concurrently, by deduction and correlation, to seek the reasons underlying these distributions and their relations to each other. Since man, seeking an outlet for his energies and satisfaction for his wants, is one of the forces which have contributed powerfully to the modification of the original natural environment and to the evolution of the "pattern" of the Earth's surface as we know it to-day, modern geography has extended its scope to include human activities in relation to the physical environment. Such a field, however, is exceedingly wide, so that, as would be expected, with the increase of man's knowledge, geography has stimulated the development of many lines of inquiry now regarded as individual sciences, which still retain a geographical basis and outlook. Thus geographical research continues to render services to many sciences, and, in turn, finds its own standpoint modified by their advance. That popular interest in geography has markedly increased in recent years is evidenced by the foundation of many periodicals, which, even though they concentrate upon the more superficial aspects revealed to the traveller, serve to implant in their readers some comprehension of the diversity of the world and of the importance of geographical knowledge. Proof of a more serious preoccupation with the science is afforded by the foundation of the Institute of British Geographers, the members of

which are mainly concerned with the teaching of geography in the Universities, and the institution of Chairs of Geography in several British Universities. In this summary review of the most recent progress in geography, it will be possible only to indicate the types of problems which are engaging the attention of geographers, the methods adopted for their solution, and the extent to which this work is contributing to the advance of the welfare of the community in general. The examples have been drawn from as wide a range of nationalities as possible, but no attempt has been made to record all the important work of the last five years.

The foundation of geography is obviously a complete and precise knowledge of the physical features of the Earth's surface—mountains, deserts, rivers, lakes, and islands. Our present knowledge is the cumulative result of a vast number of journeys by explorers and travellers of many nationalities. To them also we owe much of our knowledge of the conditions in which a great proportion of the peoples of the world are living. When it is remembered that it is thus the fruit of at least five hundred years of widespread and continuous activity, it might be thought that the last five years can show very little fit to rank with the achievements of the "classical" explorers. Nevertheless, there are several outstanding pieces of exploration to record, a fact which serves to emphasize how incomplete our knowledge of the globe still is. In southern Arabia, the great "empty quarter," or Rub'al Khali, was crossed for the first time in 1930–31 by Bertram Thomas, who collected much information relating to its natural history and to the life of its nomad peoples. Central Arabia was also the scene of a long and arduous journey by H. St. J. B. Philby in the following year. Perhaps the most striking advance has been made in the Mandated Territory of New Guinea and Papua, where an area of some three thousand square miles in the interior has been opened up by officials of the administrations and prospectors in search of gold. The population of this area, a people whose existence was previously unsurmised, numbers many thousands, and, as a Stone Age people surviving into the twentieth century, is of the greatest interest to anthropologists. It is only ten years since the Russian geologist, S. Obruchev, travelled through a great mountain system in north-eastern

Siberia, previously largely unknown, and entirely misrepresented on existing maps. In eastern Asia, the existence on the Szechwan-Tibetan border of a great mountain massif culminating in a summit, Minya Gonka, of about 25 000 feet, has been revealed in detail by several expeditions, and its physical geography and glaciology described by the Swiss geologist, Arnold Heim. At the eastern extremity of the Himalayan range, Capt. Kingdon Ward has disentangled some of the problems of its alignment, and discovered a great snow range, comparable to the main Himalaya, north of the Tsang-po. In Africa, where little large-scale exploration remains to be done, most of the Sahara has been traversed, under French auspices, and Major Bagnold and other explorers have greatly extended our knowledge of the eastern Libyan desert, and the main lines of its structure and hydrology have been determined. Reference is made later to recent exploration in the polar regions.

The pioneer explorer, with his reconnaissance maps and reports, is succeeded by the surveyor and the cartographer, who provide the geographer with his first precise tool, the topographic map. The output of the national cartographic institutions in the last five years cannot be detailed here, but there are certain maps and atlases which must be mentioned, however briefly. In the period under review, the total number of the sheets of the International Million Map of the World has reached two hundred. These, drawn in a uniform style, and capable, unlike the sheets of an atlas, of being placed together to cover any practicable area, provide the student with the framework for geographical studies covering large areas of the continents. The Million Map of Hispanic America, the work of the American Geographical Society, in style closely resembling the International Map, has made considerable progress, sixty out of the total of a hundred sheets having been issued by 1935. This map embodies much unpublished cartographical material, railway, engineering, and other route surveys, which is not otherwise generally available. The *Atlas de France*, in course of publication, is another landmark in cartography: all the maps are new, their scale ranging from 1 : 250 000 to 1/5 M. Physical, economic, and human geography are treated in detail, in accordance with the best

modern technique, and when complete, the Atlas will form a contribution of first importance to the geography of France. The revision of the Ordnance Survey of Great Britain has begun, called for by the development and re-distribution of industry and population, and in the fifth (physical) edition of the One Inch Map, the Survey are producing a map to rank with the best achievements of modern cartography. In connexion with this revision, the possibilities offered by air survey are being examined.

The maps already mentioned are largely works of compilation or revision. Elsewhere, initial surveys have been begun during this period. In Australia the Military Survey Section is at work and has already produced some sixty sheets on the one-inch scale and five half-inch sheets. The output of the Section at present is about 2 500 square miles a year, but it is hoped to increase this to 20 000 square miles; by no means a large figure when the area of the continent is considered. In East Africa, the provision of that essential of a topographic survey, a framework of geodetic triangulation, has been carried a step farther by the extension of the triangulation from north-eastern Rhodesia through Tanganyika Territory to Ruanda, a distance of 360 miles, by a party under Major Hotine. This East African Arc of Meridian, begun through the initiative of Sir David Gill at the end of the last century, is now complete, with the exception of the portion traversing part of Uganda, and the Sudan. The importance of such work as a contribution to economical and accurate mapping, and so to the ordered development of communications and natural resources, can scarcely be exaggerated. This arc will be linked to that extending from the Arctic Ocean to the Mediterranean, work on which has been promoted by the International Union of Geodesy and Geophysics. The results derived from this, in conjunction with similar operations in other continents, will afford further data for the figure of the Earth, and ultimately will increase the accuracy of the mapping of the world.

The application of aerial photography is being continually developed. A good demonstration of its value, supplemented by a rapidly working ground party, was given in 1932 and 1933, when the whole of south-east Greenland between the ice-cap and the sea was mapped by a Danish survey party.

A large area in the Anglo-Egyptian Sudan has also been mapped economically from air photographs. The main advance in technique has been in the method which can be described in essence as "plane-tabling from the air." By a development in the use of oblique photographs, evolved by the Survey of India, altitudes can now be rigorously determined.

The progress in the various branches of geography can best be estimated by a rapid review of the work accomplished by the more important expeditions of recent years. Upon these expeditions numerous scientists have co-operated in the solution of definite problems. For much of the period, a Swedish-Chinese Expedition, under the leadership of Dr. Sven Hedin, was at work in Central Asia. The area studied comprised Eastern Turkestan, particularly the Lop Nor basin, portions of the Tien Shan and the Tarim basins, while members of the party made journeys through little-known portions of north-east Tibet. The cartographical results of the expedition alone will, when published, form a considerable contribution to our knowledge of Central Asia, more particularly those relating to the conditions due to the formation of the "new" Lop Nor in 1921 and to the Kum-Daria. The physical history of this region was carefully studied, and important light thrown upon the question of climatic change. No evidence was found to support the theory of continuous and increasing desiccation in Central Asia during historical times. In this connexion may be mentioned the conclusion reached by Col. Schomberg as a result of his several journeys that the evidence sometimes adduced to support this theory—deserted settlements, failure of water-supplies, etc.—is to be explained on other grounds. On the conclusion of the main expedition, Sven Hedin undertook on behalf of the Chinese government an expedition to Hami to reconnoitre routes for proposed motor roads by which it is hoped to link up China and Sinkiang for economic development. In the course of this, further geographical information of importance was obtained. Much exploration and scientific work has also been accomplished in the Himalaya—to mention one other area of Asia, and a record of this is to be found in the *Himalayan Journal*, begun in 1929. The Yale-North Indian Expedition, under H. de Terra, in

addition to geological work, has also contributed towards an understanding of the desiccation problem. From a study of lake levels in Tibet, glacier movements, and oscillations of precipitation, it is apparent that in recent years an increase in rainfall has occurred. The Mount Everest Expedition of 1933 and other expeditions, mainly mountaineering, have added to our knowledge of Himalayan topography, biological adaptation to high altitudes, and meteorological conditions.

Prof. Emm. de Martonne has pursued his researches into the problem of interior drainage basins, including an examination of the Andes to the north-west of Argentina. He has now distinguished a subdivision of such regions, which he calls *areic*, that is, a zone in which the climate prohibits the development of through-flowing rivers. He has shown that in the Andes an *areic* belt crosses the mountains diagonally, producing the phenomenon of a belt of high altitude relatively drier and warmer than the adjoining lowland. The wider aspects of this problem of interior drainage basins have been discussed by him in various publications of the International Geographical Union; such basins comprise one-third of the area of the continents outside the polar regions, and their study is of importance to allied sciences such as geology, geomorphology, and ecology—they are "*une réalité géographique grave de consequences, et qui n'intéressent pas seulement la géographie.*" Another expedition in South America from which, but for its untimely end, much was to be expected, was that of Prof. J. W. Gregory. His notes, however, threw some light upon the structure of the Andes, which he considered to be a dissected plateau, and of its detached outlier, the coastal Cordillera of Southern Peru.

A wide field has been covered by the Oxford University Exploration Club, which has been responsible for several expeditions in various parts of the world, the aims of which are largely biological and botanical, though reconnaissance surveys have also resulted. Thus work on Akpatok Island extended the biological work of previous Arctic expeditions: the Sarawak Expedition studied the bird life in the canopy of the tropical forest, and provided interesting details of the composition of the virgin forest for comparison with previous work in British Guiana. The island of Espiritu Santo in the New Hebrides, which experiences a hot, wet climate without

seasonal variations, afforded an opportunity for the study of breeding and flowering seasons in these conditions.

The polar regions have attracted in recent years the attention of explorers to an extent comparable to that exerted by Africa in the last century. In the North, much work has been done in Greenland, all of which cannot be recorded here. In the last years of his life, the Danish explorer, Knud Rasmussen, was carrying out extensive researches into the geography, ethnology, and archaeology of south-east Greenland. The British Arctic Air Route Expedition, led by the late H. G. Watkins, and seeking to clarify conditions on that portion of Greenland crossed by the great circle route from London to Winnipeg, devoted attention to topography (two crossings of the ice-cap and one boat journey round the south-east coast), meteorology (observations at the base near Angmagssalik and at the Ice Cap Station), and flying conditions. The meteorological observations supplement those obtained by the Wegener Expedition at "Eismitte"; and taken in conjunction they contribute to our knowledge of the general circulation of the atmosphere, and a tentative theory of Greenland as a "switch" for cyclones has been put forward by Dr. J. Georgi. The latter expedition, amongst other activities, carried out a triangulation from the west coast to "Eismitte" to determine the profile of the ice-cap, and made studies of the physical characteristics of ice and snow. Similar studies formed part of the extensive programme of the Swedish-Norwegian Expedition, under H. W. Ahlmann, to North-east Land. The glaciation was shown to be passive or recessive, and to date back into Tertiary times. Dr. Ahlmann is also engaged upon a classification of glaciers upon a geomorphological and geophysical basis. The government of the U.S.S.R. has been responsible for much work in the Siberian sector of the Arctic, including many surveys of the coast-line and Arctic islands, and the completion of the hydrographical survey from Vladivostok to Bering Strait. Perhaps the most important Russian work has been in oceanography; this has revealed the increasing volume of the North Atlantic current passing round Spitsbergen, with a consequent rise in the temperature of the water, a factor of importance in the meteorology of the whole continent.

In the Antarctic, four pieces of work require notice. The Australasian Expedition led by Sir Douglas Mawson charted several hundred miles of previously unvisited coast-line on the arc between Adelie Land and Enderby Land, and made upper air observations for the elucidation of Antarctic meteorology. Admiral Byrd and his party explored the eastern arm of the Ross Ice Barrier, and the topography and geology of the adjacent plateau, besides occupying a weather station 123 miles south of Little America. The Norwegian voyages promoted by Consul Lars Christensen have also done much exploration in Antarctic seas, and the physical conditions and biology of the waters have been continuously examined by the research vessels of the Colonial Office *Discovery* Committee, to the benefit not only of the whaling industry, but of our knowledge of the Antarctic archipelagos and of the general circulation of the southern seas. The importance of this polar work, not merely for the advancement of pure science or as an outlet for a spirit of adventure, was emphasized by Prof. E. F. Debenham in his presidential address to Section E (Geography) of the British Association in 1935, in which incidentally he pointed out that many diseases contracted in the temperate zone can be cured by residence in the polar regions; he concluded that "the world must take an interest in the polar regions."

We have now reviewed very rapidly the types of work being carried out in the field, and we turn to the correlation and handling of the facts thus collected by geographers. In describing the work of expeditions in the field, some indication has been given of the problems of physical geography which are now receiving attention. Here it is possible to refer only to the work of one of the most active Commissions of the International Geographical Union—the Commission on Pliocene and Pleistocene Terraces. These terraces, which can be traced along many of the coasts and river-valleys of the continents, have had an important influence in the distribution and development of early man. Two theories have been evoked to explain their formation—the *tectonic*, which assumes a raising of the land masses, and the *eustatic*, which assigns them to variations in the level of the seas. Under the auspices of the Commission, the results of a number of studies of terraces in various parts of the world

have been published in three Reports and the nature of the problem more exactly defined. Though the origin of these terraces has yet to be finally established, the parts played respectively by a rise in the level of the land, by variations in sea-level, and by climatic variations in producing river-terraces, are being clarified, and the realization of the complexity of the subject must contribute to its eventual solution. The work of the President of the Commission, Prof. E. Hernandez Pacheco, and of Prof. D. W. Johnson requires at least passing mention here. Another important contribution to the subject is H. Baulig's *The Changing Sea-Level.* The larger problems of the structure of the Earth's crust lie outside the scope of this review, but it is legitimate to cite the work of the Cambridge Gravity Survey Expedition in East Africa led by E. C. Bullard, the results of which are held to confirm the "compression" theory of the origin of the Great Rift Valley, as against the "tension" theory.

In general geography as a whole, no great advance comparable to the "major natural regions" concept of Herbertson or the "human geography" of La Blache is to be recorded; the work has lain rather in the correlation of phenomena and the development of methods of treatment. A tendency to regard the boundaries of natural regions as zones and as liable to fluctuate, rather than as rigid dividing lines is apparent in modern geographical thought. It is also to be observed that in all branches of geography the student is becoming increasingly aware of the necessity for giving adequate attention to the "time" or historical element. Both these ideas are expressed, for example, in the German "Kulturlandschaft" school led by Passarge. A further tendency to concentrate upon the study of human geography is also noteworthy. Here the goal is the "study of the geographical environment in order to achieve harmony with it," and Prof. Roxby in the address from which this is extracted, goes on to define human geography, as the study, first, of the "adjustment of human groups to their physical environment" and secondly, of the inter-regional relations. One of the important pieces of work undertaken in this category by a Research Committee of the British Association on the initiative of Prof. Ogilvie was an investigation of the human geography of Inter-tropical Africa. Thirty reports

were obtained from administrative officers of Northern Rhodesia, from which it was possible to arrive at a sound knowledge of native life in its geographical setting, and especially of the effect of European civilization upon the native standard of living, organization, industry, and migration. The full details are to be found in Prof. Ogilvie's presidential address to Section E of the Association in 1934. Another co-operative undertaking in human geography is the study of the "pioneering process" in regions of recent settlement in Canada, stimulated by Dr. Bowman's work on a wider field entitled *The Pioneer Fringe* (1931). The results of this research by geographers and economists, which are being published in a series with the general title of *Canadian Frontiers of Settlement*, edited by W. A. Mackintosh and W. L. G. Joerg, throw much light upon the conditions requisite for successful settlement, and should prove of great value when large-scale development is again under way.

The United States of America afford an example of geographical research upon a large scale directed to the solution of national problems. As part of the national policy two bodies were established, the first in point of time, a Science Advisory Board, and secondly a National Resources Board, the function of the latter being to present "a program and plan of procedure dealing with the physical, social, governmental, and economic aspects of public policies for the development and use of land, water, and other national resources." A report of the former on "Land Resource and Land Use in relation to Public Policy" was drawn up by Prof. C. O. Sauer; this treats the subject from the point of view of the mapping of the land, and the distribution and movement of the population, and concludes with a summary on the geographical method of the regional synthesis. Two aspects are particularly emphasized, "climatic risks" and the surface and slope method of soil research, which includes the examination of the problem of soil erosion. The importance of this question will be realized from the statement that 35 million acres of land have been ruined by erosion. To combat this, the Soil Erosion Service is carrying out reorganization of land use practices, research into forests as agents in erosion control, and flood protection

methods. The National Resources Board has also recommended a long-range policy for agriculture, designed to meet the anticipated growth of population, by increasing the arable land by irrigation, drainage, and clearing, and by "retiring" some 25 million acres of land economically unsuited for agriculture. This scheme is probably one of the best examples of "applied geography" planned, for its conclusions are based upon work in all branches of geography, and it can be carried out only on the basis of a complete topographical survey, as the Board clearly recognized.

Another survey of the human and natural resources, though naturally not so comprehensive, is contained in the co-operative work *New England's Prospect*, 1933, published by the American Geographical Society, which contains good piece of geographical description by J. K. Wright.

In Great Britain, the Land Utilization Survey provides a basis which contributes in some measure to an evaluation of national resources. The survey, much of which refers to the year 1931, has mapped the utilization of land, distinguished in six categories, throughout Great Britain, and the results are being published in sheets which correspond to those of the one-inch Ordnance Survey. Such a survey, in addition to its historical and economic value, possesses considerable practical importance. It has already been used by several public authorities in drawing up regional planning schemes, where it is important not only to preserve existing amenities, but to fit the scheme into its natural environment. Its value to agriculture hardly requires to be stressed. By comparison with existing historical records, it is possible to arrive at an understanding of the trend of agricultural development, and to take steps, for example, to prevent the loss of good farming land, which in this country is irreplaceable. All such questions of development require a careful weighing of the social advantages and disadvantages, which can be done only when such a survey exists. It therefore forms the basis of all large-scale planning. The survey is incidentally an example of co-operative fieldwork, for it was carried out through the agency of educational authorities and youth organizations.

One way in which the adjustment of human societies to their environment is displayed is in the form and distribution

of their settlements. A great deal of work in the study of rural settlement has been initiated by the "Commission de l'Habitat Rural" of the International Geographical Union, and the numerous papers presented at the congresses of Paris and Warsaw are evidence both of the interest aroused in geographers and of the development of a systematic method of treating this subject. Formerly, it was customary to explain the distribution and character of rural settlements largely by reference to the physical features of the environment, for example the nature of the water supply, and to the ethnic composition of the population. Recent studies have tended to show that, while these play some part, an important factor has been the proprietary and agricultural systems of the particular society in question. This study, mainly through the initiative of Professor A. Demangeon, has particularly engaged the attention of French geographers, and the result of their work has been to emphasize the importance of historical documents in explaining this phenomenon. Similar characteristics of the rural population may be found in areas of contrasted physical features, and dissimilar distribution in areas of corresponding features. It has moreover been shown that a change in agricultural practice or tenure is reflected in the "habitat rural." From a consideration of the mass of data accumulated by these studies, M. Demangeon has evolved a formula for the adequate cartographic representation of the degree of dispersion.

The distribution of population in general has also received attention; an international map of world population is in preparation, and two population maps of Great Britain have been published by the Ordnance Survey. The development of town plans, the sphere of influence of large urban centres, the localization of industries, and the character of agricultural regions, have been studied with reference to the geographical environment. The regional approach is being increasingly applied to the study of economic geography, to the exclusion of the merely quantitative treatment of production and exchange, and with it the conception of inter-regional balance. It is impossible to give here examples of the work done in the various branches of geography mentioned above, but some idea of the trend of studies can be obtained from the titles of papers read to Section E

of the British Association in recent years. Those which relate to the British Isles will provide the material for a detailed geographical study, the basis of which is provided by the work published on the occasion of the International Geographical Congress of 1928: *Great Britain: Essays in Regional Geography by twenty-six authors*, edited by Prof. A. G. Ogilvie.

The study of historical geography, formerly mainly concerned with the tracing of the changes in political boundaries and the courses of military campaigns, has been considerably reformed. One aim is now recognized as the reconstruction of the regional geography of the past, employing as far as possible the methods applied to the study of modern conditions. In this work, geologists, archæologists, ecologists, and historians have co-operated with geographers. For early periods, it is essential to determine the characteristics of the soil and the vegetation cover of the region under consideration, which in turn are dependent upon the drift geology. It is here that the assistance of geologists in explaining historical distributions is valuable, and as an example of this kind of work may be cited various studies by Dr. Wooldridge and others. In his paper, written in co-operation with Mr. Smetham—"The Glacial Drifts of Essex and Hertfordshire and their bearing upon the agriculture and historical geography of the region"—he has shown the persistent agricultural importance of this region, in contrast to the London clay area to the south, which explains the concentration of settlements therein until well into the Middle Ages, and thus the former relative importance of Verulamium and Camulodunum. A somewhat similar method has been applied by H. C. Darby to the elucidation of the Domesday geography of East Anglia. Further assistance to the student of historical geography has been provided by the initiation of the Ordnance Survey series of historical maps of Britain, and of the International Map of the Roman Empire. The value of a knowledge of the development of geographical thought in interpreting history has been demonstrated by Professor E. G. R. Taylor. Her two volumes on Tudor geography trace the influence of current geographical theories, however inaccurate, upon the actions of statesmen and explorers at a turning point in British history.

Finally, brief mention must be made of a branch of geography which has hitherto received little attention. In 1920, Sir Francis Younghusband pleaded for the systematic study of the æsthetic aspect of geography. This has been developed by Dr. Vaughan Cornish during the last fifteen years, on the basis of extensive observations in many parts of the world, and the main principles of scenic geography may now be regarded as scientifically established on the basis of psychology and of physiological optics.

IV

BOTANY

By Professor F. E. Weiss, D.Sc., LL.D., F.R.S.

BOTANY has become such a much divided subject and its various branches differ so widely in their treatment and outlook, that it is difficult to give a homogeneous account of the progress that has taken place during the last five years in botanical science. All that can be done is to draw attention to some of the lines of advance and to emphasize those which may be considered to be of more general interest. It must be remembered, however, that even the more abstruse discoveries not only contribute to the progress of science as a whole, but may at some future date become of considerable practical and economic importance.

In considering the advances made in botany during the past few years, it may be best to begin with some of the recent investigations in plant physiology, in some respects the most active branch of botany to-day.

GROWTH-PROMOTING SUBSTANCES OR HORMONES

It is more than fifty years ago since Sachs as a result of his physiological experiments put forward the view that the growth of the various parts of a plant, such as the flowers or roots, was dependent upon specific chemical substances. By this hypothesis he anticipated the later discovery of growth-promoting substances secreted in animals by definite internal glands. Until recently these so-called "hormones" were only known to occur in animal organisms. In 1927, however, F. W. Went was able to isolate a substance of growth-promoting nature from the growing tips of young oat seedlings. If such young seedlings were decapitated and the tips were placed on small blocks of gelatine or agar a chemical substance diffused into the latter and such charged blocks could promote growth when placed upon the decapitated seedlings. Thus he showed that growth was due to some definite substance, which could be extracted from the growing tips of the plants. To this substance he gave

the name of *auxin*, from the Greek *αὔξειν*, "to increase." Since Went's discovery innumerable further investigations have taken place, particularly during the last five years, and it has been shown that, in addition to two forms of auxin, the chemical composition of which is now known, a similar growth-promoting substance, *heterauxin*, can be extracted from various fungi, particularly from moulds and yeast cells. Its chemical nature proves to be indol-acetic acid. Auxins are apparently formed in the leaves of plants and are thence transmitted to the various growing points. By a special method it has been possible to detect them in root tips as well. Similar plant hormones of considerable potency have been found in the pollen of many plants, the pollinia of orchids being particularly rich in such a substance. Curiously enough, fresh mammalian urine is very rich in a plant hormone, which can be extracted from it in chloroform.

These various substances not only stimulate growth in length of stem and root, but are also concerned in promoting the growth in thickness of the internal conducting tissues of the plant. Their distribution in the tissues of the plant is differentially influenced by light and gravity, and their unequal distribution causes the bending of the growing stem towards light and upwards from the soil. Whether these auxins have a stimulating activity on the protoplasm of the living cell or whether they increase the plasticity of the walls and their consequent expansion is still a matter of doubt.

This addition to our knowledge of fundamental facts connected with growth may appear to be of theoretical rather than of practical importance, but there is no doubt that it can and is indeed already being used in certain horticultural problems. A method of applying the various natural and synthesized hormones mixed with lanoline to the outside of stems has shown that the production of adventitious roots is stimulated, and in this way it may be possible to propagate by cuttings or layerings some plants which up to now it has been difficult so to propagate. It is also quite possible that the use of plant hormones may facilitate or accelerate the grafting of plants, since it has been shown that they promote the growth of callus, the tissue by which grafts are united.

Vernalization and the Phasic Development of Plants

The effect of differences of temperature and of light on the germination of seeds and the development of plants has long been a special field of investigation. Kinzel discovered some years ago that the seeds of gentians and many other Alpine plants require to be exposed to frost if germination is to be successful, an indication that it is better to sow them in autumn than in spring. During the past few years the Russian scientist Lysenko has paid special attention to the early stages of development of some of the most important crop plants such as wheat and cotton. He observed that certain varieties of winter wheat, sown in spring when conditions are favourable for growth, were unable to develop to maturity, i.e. to produce ears; and his further investigation showed that these winter wheats required to pass through a comparatively long period of growth at a low temperature. Further investigation showed that all plants require at the outset of their development a comparatively low temperature ranging from 0° to 20° C. This he calls the *thermostage* of development. He then discovered that this stage may be passed through by the plant at a very early period of its development when the grain has just begun to sprout but the embryo has not yet broken through the seed coat. By subjecting seeds at this stage of their development to cold he has been able to hasten the development of the plants to maturity and was able to obtain good yields of grain from winter wheat sown in spring, provided the seeds had been subjected to cold in the partially germinated condition before sowing. This pretreatment of the seeds which is carried out before sowing has been called *vernalization*. It has been undertaken in many countries in every part of the world and has proved successful with the most varied crop plants. Though primarily this discovery is a purely scientific advance in our knowledge of plant life it is obviously of great practical importance, as it enables the agriculturist to hasten the development of his crops to maturity and thus to develop agriculture in regions in which the normal growing season is short.

Lysenko also discovered that the early thermostage of

plant development is followed by a *photo-stage* in which certain requirements as regards light have to be fulfilled. It has long been known that some plants require for the development of their flowers and fruits days of considerable length such as occur during the summer in northern latitudes. These so-called *long-day plants* do not mature well in lower latitudes. Plants adapted to the regions of more equal distribution of day and night are called *short-day plants*, and these, it now turns out, require a certain amount of darkness or low light intensity for their normal development. By giving them the necessary ten or fifteen days' darkness in the pre-sowing stage when the seeds have just begun to germinate, these plants can be induced to pass the photo-stage before being sown, and can achieve all their subsequent development perfectly well under northern conditions of almost continuous illumination.

Respiration and Fruit Storage

Respiration is one of the fundamental processes of all living organisms. It consists, in plants and animals alike, in the taking in of oxygen and the giving out of carbon dioxide, the process being essentially one of slow combustion, the tissues of the plant losing some of their substance but gaining the energy necessary for their vital activities. The more vigorous these are, the greater the amount of respiration, and during active respiration in confined surroundings the temperature may be considerably raised as in the process of malting. Respiration has always been a favourite subject of physiological experiment, and a good deal of information has been accumulated concerning the effect of temperature on the rate of respiration, and dealing with the nature of the chemical changes that take place in the plants. More detailed and intensive study of the subject has been made possible by a new form of katharometer invented by Leach and Stiles, which is based upon the varying thermal conductivity of gases. The amount of oxygen and carbon dioxide can be measured by their electrical resistance and recorded by clockwork. This method has been used to some purpose in determining the rate of respiration of seeds at various stages of their germination.

But while many experiments in the past have been of

general scientific importance, a considerable amount of very useful work* has been carried on under the Food Investigation Board of the Department of Scientific and Industrial Research and at the Low Temperature Station for Research in Biochemistry. Kidd and West, by studying the respiration under varying conditions, particularly of temperature, have brought together a large body of facts which have materially affected our knowledge of the best conditions for the storage of fruit. While much of this work was carried out before 1930, further investigations have continued on these lines during the last five years.

Various investigators have been able to show that stored apples during the early stages of senescence show a marked acceleration of respiratory activity followed later by a decided deceleration. Apparently the death by fungal disease intervenes after approximately the same total amount of carbon dioxide has been evolved, but at a temperature of only 2·5° C. this will not occur until the apples have been in store for about 205 days, whereas the duration of life of the apple will be only 97 days at 10° C. and only 41 at 22·5° C. The advantage of low temperature storage by reducing the respiration is therefore apparent.

Another method of reducing the respiration of stored fruit and therefore increasing its keeping capacity is to enrich the surrounding atmosphere with carbon dioxide and reduce the amount of available oxygen. It was thought at one time that this gas-control method might take the place of temperature-control, but it turns out that if gas control alone is used, self-heating of the apples takes place with a consequent decay of the fruit. Serious gas injury is found to take place both at a low temperature of 1° C. (34° F.) and also at 10° C. (50° F.), but no injury takes place at 4° C. The most efficient way of maintaining the keeping quality of apples is therefore to store them in an atmosphere of 10 per cent of carbon dioxide and 10 per cent of oxygen at a temperature of 4° C. (40° F.). This gives results greatly superior to cold storage in the ordinary atmosphere. In the case of other fruits similar methods of storage are now being investigated.

* The commercial aspects of this work are touched upon in the concluding section, on "Science and Industry."

Pathology and Mycology

The study of the diseases of plants is intimately bound up with that of fungi (Mycology) since these primitive plants are largely the cause of plant diseases. While during the last five years no striking advance has been made in our methods of combating the diseases, a good deal of intensive work has been carried on connected with the life history and the development of fungi, and this cannot fail to be ultimately of advantage in controlling the development of the harmful, i.e. the parasitic, forms. Thus our knowledge of the life history of the fungus causing diseases known as *rusts* was materially advanced during the late twenties by an important discovery made by Craigie, of which we now have a fuller published account. Craigie discovered that certain small reproductive organs called *spermatia*, which had been considered to be rudimentary and functionless male organs of the fungus are definitely concerned with the reproduction of the plant. The small pustules which appear on the upper surface of the leaf of the affected plant contain minute spores which are carried by flies, attracted by a small drop of secretion, from plant to plant. Apparently two spores of different strains are required for the production of the later fruiting bodies. In the higher fungi definite sexual organs such as are found in the lower forms seem to have been lost, but, as Blakeslee showed many years ago, for some of our moulds two strains of the vegetative part of the plant exist (*heterothallism*), and filaments of the two strains require to unite vegetatively before active spore formation can take place. The investigations of the past few years have shown that heterothallism in one form or another occurs in many members of all classes of fungi, and that it may play a decisive part in promoting the effective fruiting of these forms.

In simplicity of organization there are many likenesses between the algae and fungi, the latter differing mainly in their necessity for organic material as nutrition, since they cannot make up their food from simple beginnings. Many algae have long been known to include an alternation of generations in their life history, one generation being a sexual phase, the other an asexual one reproducing by spores of asexual origin not arising from a fusion of elements.

Such an alternation was unknown in the fungi until 1930, when Kniep described the condition in *Allomyces javanicus*, a member of the lower fungi. In that species, motile gametes are formed, but asexual spores belonging to another generation provide a more prolific means for the spread of the fungus. Such a state of affairs may be found in many algae, and its discovery in a fungus is a welcome advance.

In the primitive or possibly reduced fungi, known as yeasts, Winge has recently described a similar occurrence. For certain forms the endospores may develop singly, but they then give rise to a haploid colony of limited size. On the other hand, if the spores conjugate immediately on germination they produce a more vigorous diploid vegetative phase. These results confirm the earlier investigations of Kruis and Satava.

During the cultivation of fungi on artificial media experiments have been carried out to test the effect of variations in temperature on the development and nature of the fungus. Barnes has shown that if the spores of various fungi are exposed to heat they may produce on germination not only temporary but also permanent changes in the fungus. Dickson experimenting on the ultra-violet and X-rays produced a number of variants which apparently remained permanently altered.

Among the discoveries of more than passing interest is that by Drechsler of a whole group of terricolous fungi, which destroy the amoebae found in the soil. Now the microscopic fauna and flora of the soil has been shown to be of considerable importance in connexion with the fertility of the soil. Since the microscopic amoebae destroy many of the useful bacteria, the removal of the amoebae by a larger fungus may be of sound economic advantage. Moreover some of these newly discovered fungi prey on small eelworms or nematodes, and they may possibly become important as biological controls for eelworm diseases.

Another direction in which mycology has become of importance to industry is in connexion with combating a fungus *Byssochlamys* which has made its appearance in some of the newly established canning factories and has caused some considerable losses.

As is well known, fungi, including the more primitive

forms of bacteria, are by no means all parasitic or harmful to the higher plants. It has been stated above that many bacteria inhabiting the soil help to increase its fertility which they do by fixing some of the atmospheric nitrogen and rendering it thus available to the higher plants. One of these organisms, *Bacillus radicicola*, actually inhabits the roots of leguminous plants such as peas, beans, clover, lucerne, apparently in a condition of symbiosis or partnership, certainly benefiting under normal conditions the leguminous plant by increasing its nitrogen nutrition. It has been discovered, however, by Thornton, working at the Rothamsted Experimental Station, that under certain conditions and particularly in the older root nodules, the bacteria may become parasitic on the lucerne or clover plants. This knowledge is important in connexion with the cultivation of these crops.

In other plants in which higher fungi enter into a similar symbiotic relationship with flowering plants to form what we term *mycorrhizal* growths, it has been shown that varying conditions determined the greater or less resistance to the internal growth of the fungus. In the case of Citrus it has been shown that an adequate supply of stable manure and the application of cover crops render the roots more resistant to the invading fungus than when artificial chemical manures are employed.

Virus Diseases

Among the diseases which have probably been most intensively studied during the past few years are those caused by viruses. In animals and man many diseases such as foot and mouth disease of cattle, dog distemper, measles, are known to be produced not by bacteria, but by an agent or organism which is usually invisible under the microscope and which, unlike the bacteria, will pass through a porous porcelain filter. Among plants a large number of virus diseases are now known. They attack many important crop plants such as potatoes, tomatoes, maize, tobacco, etc., producing either a mosaic-like discoloration of the foliage or curious deformations of growth, or killing off certain tissues, cause black or brown spots or ring-like markings. It is now also known that curious striping of flowers such

as can be observed in the wallflower, in stocks, and in the so-called "breaking" in tulips, where the uniform colouring of the flower is changed to a somewhat picturesque striping, is due to a virus disease. Being so intangible it is difficult to define what a virus really is, but we may say that a virus is a pathogenic agent below or on the borderline of microscopic visibility, which agent causes a disturbance of the function of living cells and is regenerated in the process.

In Britain the virus diseases of plants have been very carefully studied by Dr. Salaman and Dr. Kenneth Smith at the Potato Virus Research Station at Cambridge. Many interesting features have come to light. As the viruses do not form spores like the parasitic fungi, the transmission of the virus from plant to plant has to take place in some other way. Careful experiment has shown that the disease is spread by greenflies, which after having fed on an infected plant can transmit the disease to a fresh plant when they puncture its cells with their mouth parts while feeding. Apparently, however, there is a definite latent period, the insect not being infective until the virus has been in its body for some little time. Once the plant has become infected by the insect *vector*, as it is called, it takes three or four days for the virus to spread throughout the plant.

A plant infected with one type of virus may be thereby rendered immune to another form. Whether it will be possible to inoculate the plants with a disease of less severity as in the case of some bacterial diseases, remains to be seen. Curiously enough it has been stated that if a plant virus is passed through the body of a rabbit the serum of the latter will contain anti-bodies that will confer immunity on plants.

In view of the fact that crops—potatoes, for instance—may have their yield reduced by 50 per cent by certain virus diseases, it is very important that some method should be evolved of combating these diseases. Luckily some varieties of potatoes are immune to some, at all events, of the virus diseases. In other varieties the disease may take upon itself a different form, while in some cases the plant shows no reaction to the disease when infected, but can act as a "carrier" and can transmit the virus, though the latter has apparently no effect on its tissues.

An account of practical measures adopted to combat some

of the virus diseases affecting our crops will be found in the section dealing with Agriculture.

Genetics and Cytology

Genetics, the science of plant breeding, has been actively carried on in all parts of the world and particularly at the various experimental stations, and though, in the past, it has led to an enormous improvement of various crop plants, it has not of recent years yielded striking results. Useful work has been done at the Cotton Research Station in Trinidad in experimental hybridizing of various wild strains of cotton with a view to obtaining more disease-resistant varieties, and the Russian government has been particularly active in bringing together, breeding, and acclimatizing economically useful plants from all parts of the world with a view to rendering their country independent of imported supplies. Interesting results have been obtained at Kew by Dr. Turrill and E. Marsden Jones, by selection and breeding of characteristic and distinct varieties of some of our British wild plants, a matter of importance to systematic botanists.

But the greatest activity has been shown of recent years in the detailed study of the chromosomes of plants, those microscopic units of the nuclei of the vegetable cells, which are now recognized as the carriers of hereditary characters. It may be said without fear of contradiction that the scientific practice of plant breeding cannot be carried on without a definite knowledge of the chromosomal constitution of the plants to be dealt with.

Most species of plants have a definite number of chromosomes, usually an even number, of which one-half has come from the male and half from the female parent. In the preparation of the reproductive cells the number is again reduced by a segregation of the chromosomes to the original or fundamental number. If the number were not thus reduced prior to the formation of reproductive cells, the number of chromosomes would constantly be doubling itself at fertilization. As a matter of fact this does occasionally take place, and we find in Nature certain forms or varieties which in place of the normal two sets of chromosomes (diploid plants) have four sets and are spoken of as

tetraploids. By further omission of the normal reduction before reproduction they may increase their chromosomes to eight sets (octoploid) or by breeding with other forms possess six sets (hexaploids). On the other hand, the union of a diploid and tetraploid plant will produce a triploid plant with an odd number of chromosomes ($3n$). We also find pentaploid plants with five sets of chromosomes.

Plants with a larger number of chromosomes than the normal two sets are often characterized by more vigorous growth and greater size, though this is not always the case. It is of interest to note that many of our cultivated plants have a larger number of chromosomes than have the wild forms. Probably in selecting in the past the more vigorous plants, man has selected tetraploids in place of diploids. Knowing as we do now from cytological studies, i.e. from an investigation of the details of the cells, the nuclear constitution of plants, we are able to forecast many results of plant breeding. Experimental and theoretical considerations tell us that plants with an odd number of chromosomes (triploids and pentaploids) will often be sterile as they cannot divide their chromosomes evenly prior to the formation of their reproductive cells. On the other hand, should they produce offspring, these will often be malformed or themselves sterile. Also the union of a diploid plant with a tetraploid will produce a triploid which will probably be a sterile plant. A large body of facts has been gained by the study of cytology, which are of the greatest importance in plant breeding and which have already explained many results which were formerly little understood.

Thus it has long been known that a large number of our cultivated fruit trees were either self-sterile or had certain incompatibilities. A careful and detailed investigation of their chromosomes has been carried out by various investigators at the John Innes Horticultural Institution and at East Malling. It has been shown that many of our cultivated cherries, plums, raspberries, apples, etc., are polyploid, i.e. have more than the normal number of chromosomes. Some of these are self-compatible, i.e. they set a full crop with their own pollen, others are self-sterile but may yield good crops when pollinated with other compatible varieties. A knowledge of these facts is, of course, very important in the lay-

out of orchards if a good yield of fruit is to be obtained. From this point of view as well as for future breeding experiments, cytological investigations have been and will be of primary importance.

The study of nuclear constitution has been carried on with wild plants as well, and in this connexion very valuable information has been obtained concerning the relationship and the geographical distribution of plants. The nuclei of most of the species of some families of plants have been investigated, as for instance, the Cruciferae by Dr. Manton, the Salicaceae by Dr. Blackburn, and of definite genera such as the Primulas by Dr. Bruun, and it has been found in general that the relationship of forms as at first settled by morphological characters is borne out by the nuclear constitution. In some cases, however, the latter has been able to solve certain difficulties of classification. It has also been possible to correlate the greater geographical distribution of some forms with the greater vigour of the plants due to their tetraploid nature.

It is well known that some species of plants do not form natural hybrids and cannot be artificially hybridized. This can now be explained by the incompatibility of the number of their chromosomes and the sterility of such hybrids when they are formed can be similarly explained. Where species have the same number of chromosomes and form hybrids the latter tend to disappear by segregation of the subsequent descendants, which by the Mendelian rules of inheritance revert to the parental characters. Occasionally, however, a species hybrid may be produced which not only shows particular vigour of growth but also breeds true. A well-known case of this is the rice grass, *Spartina Townsendii*, which has infested and filled up Poole Harbour, having appeared only comparatively recently in British waters. It turns out to be a hybrid of *Spartina alterniflora* and *S. stricta* and possesses a complete set of chromosomes from both its parents. It is therefore a tetraploid plant and this explains both why it breeds true and also why it exhibits such great vegetative vigour. Reference is made in the section on "Agriculture" to the use of *Spartina Townsendii* in connexion with reclamation works. *Spartina Townsendii*

behaves like a true species and may be regarded as a species which has recently originated. It is of interest in connexion with the theory of Lotsy that all species had arisen by hybridization.

It is, of course, possible that a number of existing species may have originated in this way, but so far we know of very few cases in which this is likely. Müntzig by crossing two species of Galeopsis obtained as is common with species hybrids, highly sterile forms. But from a single seed he obtained a tetraploid which was fertile and bred true. It was indistinguishable from *Galeopsis Tetrahit*, the hemp nettle, and it is therefore possible that far back in the past this natural species may have arisen as a cross between *Galeopsis pubescens* and *G. speciosa*. Genetical experiments coupled with cytological investigations may therefore in the future throw some light on the origin of species which De Vries asserted should be an "object of experimental investigation."

The Past History of Plants

In addition to the origin of species, that of the great groups of plants making up the vegetable kingdom has always been a subject of inquiry and has occupied the attention of numerous palaeobotanists.* In the earlier decades of the present century the discovery by Kidston and Lang in some early Devonian deposits of Scotland, of a group of primitive vascular plants, the *Psilophytales*, took the origin of the first land plants back to a much earlier period than was formerly thought to be the case. Since 1930 still earlier vascular plants have been discovered in some Silurian deposits of Australia and have been fully described by Lang and Cookson. Some of them are of considerable size and comparatively complicated structure so that they were probably preceded by other and simpler forms.

At the other end of the series of plants, some further advance has been made in our knowledge of the ancestry of the flowering plants, though at the moment it is still uncertain whether the Caytoniales described by Hamshaw Thomas were truly angiospermous, pollen grains having been discovered inside some of the seed-bearing structures.

* As previously indicated in the section on "Geology."

The last phase in the history of our vegetation has received considerable attention during the last five years in all northern countries by the adoption of Erdtman's method of the analysis of the pollen grains found in our peat deposits. By a careful determination of the pollen grains, which have been preserved in the peat, and by an analysis of the proportionate number found at various depths in the peat it has been possible to determine with some degree of accuracy the nature of the vegetation which covered the various countries at successive periods since the great Glacial Period which so largely destroyed the previous vegetation, the peat deposits being generally considered post-glacial in their development. The former vegetation, varying to some extent in different regions, shows a succession of birch, hazel, pine, oak and beech forests, each successive stage correlated probably with the climatic conditions. We have therefore been able to some extent to determine the climate during the late Quaternary Age, an early boreal period being followed by an atlantic period with subsequent sub-boreal and sub-atlantic periods. Thus we are able to picture to ourselves something of the climatic conditions of prehistoric times, their history being recorded by the preserved remains of our peat deposits.

V

ZOOLOGY*

By G. R. de Beer, D.Sc.

IN *Genetics* the theory that Mendelian factors or genes† are located at definite places in linear order along the chromosomes has been established beyond doubt by C. Stern, (1) by combining genetic experiments with cytological observations. Stern worked with a stock of Drosophila in which both ends of a particular pair of chromosomes were of abnormal shape and visibly distinct. On breeding from such individuals, those offspring in which a reassortment of the characters inherited from the parents had occurred were also the ones in which examination of cells under the microscope showed that interchanges had taken place between the ends of the chromosomes.

This crucial experiment also proves the validity of the theories of "linkage" and "crossing-over" in explaining the assortment of different pairs of genes carried in the same chromosome, and shows further that the principle on which "chromosome-maps" have been compiled from genetical data are thoroughly sound. It may also be mentioned that observation of cases in which pieces of chromosomes have been detached and lost have confirmed the correctness of the localization of the genes in the maps as regards their linear order, while providing interesting evidence as to their absolute distances apart. (2) The cytological correlates of all these genetical facts have now been placed on a firm basis by C. D. Darlington. (3) In this connexion mention should be made of E. Heitz's discovery (4) that the chromosomes in the larval salivary glands of Drosophila are seventy times longer than normal and that they show bands in the regions where the chromosome-maps indicate that genes are located. Further, T. S. Painter has shown that (5) these

* This section and that on "Biochemistry" necessarily touch upon certain subjects, common to both, which it would have been inappropriate to exclude from either one or the other.

† For a definition of this term and further discussion, see the section on "Anthropology."

bands correspond section for section with the loci of the genes, and that when genetic evidence indicates that genes have been lost or groups of genes inverted, corresponding changes may be observed in the bands.

R. A. Fisher's demonstration ([6]) of the relation between a gene and the character which it controls is of capital importance. Previous work had led to the view that genes were causally related to the respective visible characters in such a way as to justify the conclusion that any given gene, given suitable external conditions, would always produce "its" character. It is now realized, however, that the production of a visible character or phenotype is conditioned not only by the single pair of genes concerned and by the external environment, but also by the interaction of all the other genes (the gene-complex). Recombinations of the allelomorphs of these other genes have been shown to be capable of bringing about a *gradual and continuous* change in the character, i.e. of altering the mode of action and effects of any given gene. Further, it has been shown that the direction of such change is controlled by selection. This is particularly evident in the case of stocks of Drosophila which at the start of the experiments were homozygous for the recessive gene and character "eyeless," and were inbred.

After some generations of inbreeding, the stocks showed high mortality, but the survivors had normal eyes. Yet the recessive "gene for eyeless" was still there and normal, as proved by crossing some of these phenotypically eyed but genotypically "eyeless" individuals with the normal.

The explanation is that during the inbreeding, the (heterozygous) other pairs of genes have recombined in all sorts of ways to produce different gene-complexes, and that gene-complex has survived—i.e. has been *selected*—in which the deleterious effects of the "eyeless" gene are suppressed.

In other words, genes are either dominant or recessive because they have *become* the one or the other as a result of selection of the gene-complex. The most elegant proof of this was furnished by E. B. Ford, ([7]) who showed that the different effects of a single gene could be modified in different directions by selection. This work shows why it is that the majority of advantageous genes are dominant; thousands of years of selection of the wild type have produced a gene-

complex in which these genes have evolved their dominance. It is also clear why the majority of genes which have mutated under experimental conditions are both deleterious and recessive: deleterious because the gene-complex has achieved a balance which any change is more likely to upset than to improve: recessive because most mutations have recurred again and again, and the gene-complex has been selected against such genes producing their effect in the heterozygote by rendering the gene recessive. The inbreeding experiment described above carries the process a stage farther and inhibits the gene even when in the homozygous state; i.e. renders it *subrecessive*. This process is probably the method of origin of the so-called *specific modifiers*.

The reality of natural selection has been well stressed by J. B. S. Haldane, ([8]) who has further pointed out that fitness to survive on the part of the individual may lead to the exaggeration of structures, and so to extinction of the species.

But far and away the most important aspect of this work is that it provides experimental evidence in support of the view that *Evolution* has proceeded by gradual change as a result of selection of variations, the variations being due to recombinations of existing genes to form new gene-complexes, and to mutations of new genes. Seldom have any views been vindicated as completely as have Darwin's in this respect.

As an example of the way in which this principle may be held to have worked in Evolution, the case of *mimicry* may be taken. ([9]) Previously, the existence of a single factor-difference between mimetic and non-mimetic forms was construed to mean that the mimic had evolved *per saltum* at one shot by mutation. It is now clear that this conclusion was illogical, and there is evidence not only of the approach of mimic to model by selection of gene-complexes, but also of the efficacy of selection in maintaining the mimicry. For it is found that in those areas where a model species is relatively less numerous or absent, the mimic species shows a variability which is significantly greater than that which it presents in areas where the model is more numerous. Incidentally it may be noticed that here, at last, is real evidence of the reality of mimicry as a biological phenomenon. ([10])

It is further to be noticed that detailed study of the

resemblances between model and mimic has shown them to be purely superficial, often involving quite different structures and pigments. This proves that mimetic resemblance cannot be explained as due to parallel or homologous mutations.

A further point of great importance is the mathematical demonstration that there exists already sufficient genetic diversity to allow of phenotypic change by recombination of genes, taking place for vast eras of time even if no more mutations were to occur. However, the direction of evolution is as liable to be influenced by new mutations as by old ones, provided that they are favourable.

The problem of the nature of the process of mutation continues to be attacked from many angles, ([11]) but it is now clear that the only agencies definitely proved to be capable of inducing mutation are short-wave radiation, high-speed electrons and, to a slight extent, heat. ([12]) Further it is evident that their action is non-directive and results merely in an acceleration of the normal mutation rate. At the same time it has been found that the short-wave radiation and β-particles occurring in Nature, are insufficient to account for more than one in a thousand of the mutations that occur.

A very suggestive line of investigation has been opened up by H. J. Muller's hypothesis ([13]) that mutations are the product of translocation, inversion, or abnormal crossing-over, resulting in the presence in one and the same chromosome of both the genes of an allelomorphic pair, or of a gene in a new position, between abnormal neighbours. It has been known for some time from A. H. Sturtevant's work ([14]) that a gene behaves differently when it is in the same chromosome as its allelomorph. This is known as the *position effect.*

As regards *sex*, mention must be made of R. Goldschmidt's final publication ([15]) of his classical work on the genetic control of *intersexuality.* The analysis of the problems of sex differentiation has been carried further by F. W. R. Brambell ([16]) and by E. Witschi. ([17]) B. W. Tucker's studies ([18]) in parasitic castration in Crustacea show that Geoffrey Smith's explanation of the phenomenon as due to a drain on the metabolism of the host is still the best. W. Nowinski has shown ([19]) that the masculinizing agent present in female

Bonellia is effective in cell-free extract as a substance which is normally responsible for sex determination in this form.

Scarcely less important than the advances in Genetics are those which have been made in *Experimental Embryology*. Of great significance from the theoretical point of view are S. Hörstadius's experiments ([20]) on sea urchin development, showing that the power of regulation on the part of separate blastomeres is due to the meridional plane of the cleavage divisions which gave rise to them, enabling them to possess portions of cytoplasm representing the whole length of the egg axis. Parts of even the unfertilized egg are incapable of regulating, if they are cut transversely to the egg axis. This inability to regulate on the part of the egg is thus shown to be due to definite mechanical reasons, and attempts like those of Driesch to explain development in terms of the activity of vitalistic factors or entelechies are not only unnecessary but demonstrably wrong. It has now been found that during a certain important (so-called *mosaic*) stage of development in all forms, regulation is impossible, and the organism is not a "whole" but a sort of composite tissue-culture of independently self-differentiating organs and parts.

W. Vogt's classical studies on the fates of the various parts of the embryo in Amphibia ([21]) with the help of *intra vitam* stains have been extended to Cyclostomes by R. Weissenberg, ([22]) Teleostei, and Chelonia by J. Pasteels. ([23]) The "mapping out" of "presumptive areas" in birds still presents some obscurities. Meanwhile, the mode of action of the amphibian *organizer* discovered by H. Spemann has been analysed further by J. Holtfreter, in a series of papers of fundamental importance. ([24])

In many other branches of the Animal Kingdom, besides Amphibia, experimental researches have revealed the presence of organizers. Prominent among these are the results of C. H. Waddington's experiments ([25]) in which he found that the primitive streak of the blastoderm of a bird embryo possesses the power of an organizer, and is able to induce the formation of a neural tube out of tissue under which it is grafted, and which would normally not have formed such a structure at all.

On the theoretical side, Waddington has been able to

carry the analysis of development deeper by distinguishing the process of *evocation*, the determination that a new axis will be formed, from the process of *individuation*, the determination of the regional character of such an axis.

The interpretation of many experimental facts concerning development has rendered necessary the formulation of the concept of *morphogenetic fields* ([26]) to account for the facts that parts of eggs or embryos can develop into wholes, that two embryos juxtaposed can regulate into one, and that regeneration can replace what has been lost, whatever it is. A "field" may be defined as a dynamic system in which all the parts are in equilibrium and in relation to one another, so that alteration to any part affects the whole. The same properties are exhibited in a qualitatively restricted way by the various areas of a developing embryo which have acquired the determination to develop into the various organs. Further, the field-concept is able to make use of Child's axial gradient hypothesis in the formulation of its structure, and of the distribution within it of morphogenetic potency. J. S. Huxley has drawn attention to the wide applicability of "field-concepts" in biology. There are the transitory fields of nervous activity in the cerebral cortex ([27]) probably associated with the apprehension of spatial relations and "Gestalt"; and growth-fields responsible for the co-ordinated deformation of organisms during development and afterwards, in addition to morphogenetic fields.

But perhaps the most striking and fruitful biological discoveries made for some time have resulted from experiments on the distribution and chemical nature of the substance which is responsible for the *evocatory* aspect of organizer phenomena. After it had become clear that the inductive effect of the organizer is manifested by the diffusion of chemical substances, J. Holtfreter ([28]) showed that this substance, which in the living amphibian embryo is confined to the organizer region, can be obtained from all parts of dead embryos, as indeed of all sorts and conditions of animal tissues.

Next, work by J. Needham, C. H. Waddington, and D. M Needham ([29]) showed that the active principle is soluble in ether; C. H. Waddington, J. Needham, W. W. Novinski, and R. Lemberg ([30]) obtained evidence to show that this

substance is probably a sterol; while C. H. Waddington and D. M. Needham ([31]) obtained induction of neural tube by implantation of synthetic hydrocarbons (sterols) which are also oestrogenic or carcinogenic.

Embryology has here established contact with the most widely diverse biological phenomena, since sterols or sterol-like substances are now known to be concerned with vitamin D (radiated ergosterol), cardiac glucosides (in digitalin), male and female sex hormones (oestrin); corpus luteum hormones, carcinogenic, and evocatory (organizer) phenomena. It is also important to note that sterols are normal constituents of animal tissues (cholesterol) and of bile acids.

By means of this work and the light which it throws in many directions, some humble and obscure results of the effect of staleness in frog's eggs have acquired first-class significance. According to the degree of staleness the developing frogs may show disturbances in sexual development, or in the development of the neural tube, or they may produce tumours. In other words, the oestrogenic, evocatory, and carcinogenic properties of sterols are all here involved, apparently as a result of some disturbance in the sterol-metabolism of stale eggs.

The demonstration of the chemical nature of the active principle responsible for the evocatory aspect of organizer activity, has rendered necessary a review of the phenomena of chemical correlation and of the *hormone-concept.*

This has recently been done by J. S. Huxley, ([32]) who has distinguished—

A. *Activators*, with specific functions in regard to differentiation.

I. Local activators:

(*a*) intracellular, e.g. Mendelian genes;

(*b*) regional, e.g. organizer evocator.

II. Distance activators:

(*a*) diffused through tissues, e.g. male hormone in frogs, neurohormones;

(*b*) circulated through the blood, e.g. "true hormones," thyroxin, etc.

B. *Para-activators*, by-products of normal or pathological metabolism: e.g. CO^2, histamin.

Possibilities of important extensions for research are opened up by F. R. Lillie and M. Juhn's discovery ([33]) that the degree of alteration of pattern induced in regenerating feathers by female sex hormone and thyroxin, is proportional to the growth rate of the feather. This is the first time that a connexion between these important sets of developmental phenomena (differentiation by hormone action, and growth) has been experimentally shown.

Very significant have been the developments in bridging the gap between the *chemical and colloidal structure* and the biological structure and functions of tissues and living matter. W. T. Astbury's ([123]) X-ray analysis of various proteins found in animal fibres are of first-class importance in this connexion. In particular, the reversible extensibility of wool (keratin) fibres has revealed the existence of a sort of intramolecular spring mechanism, which works by pulling out a serpentine overfolded "back-bone" of carbon and nitrogen molecules into a simple open zigzag, or by further condensation and overfolding. The importance of this discovery in connexion with the problem of muscular contractility is at once evident, especially when it is realized that myosin and unstretched keratin have similar X-ray pictures. On the other hand, blood fibrin gives the same picture as stretched hair keratin, while the inelasticity of silk fibrin and feather keratin is also consonant with their molecular structure as revealed by X-ray analysis. Incidentally it is of interest to note that mammalian hairs, nails, spines, horns and baleen are all of similar nature, and different from feathers, which however resemble tortoise-shell and reptilian scales; indicating that feathers, but not hairs, may have evolved from epidermal scales.

It is highly probable that the paracrystalline type of structure will be found to be responsible for many properties of the cell, especially since it is now realized that some living systems actually are liquid crystals. ([34])

No less interesting than the structure are the properties of the molecules and the parallel between these properties and the functions of the tissues. Thus unstretched hair is resistant to water and other agents; this is because in the condensed state of the molecule of keratin, the closely packed side chains prevent foreign molecules from getting

at the "backbone." Other types of fibres, e.g. the collagen fibres of connective tissue, appear to owe their water-resistant properties, as D. Jordan Lloyd ([35]) shows, to the fact that the "backbones" of the protein molecules are arranged parallel with one another and in such close proximity as to squeeze out water, and render the central molecules inaccessible to it. Altogether, it seems that the activity of tissues as regards growth, etc., is correlated with the presence of molecules whose structure permits of chemical activity and accessibility to water, while the inactive tissues contain molecules arranged in such a way as to prevent ingress of water and chemical activity. And, to use Astbury's words, proteins "offer the possibility of large-scale and reversible changes of form through changes of physical and chemical environment."

Problems of cell-division may perhaps also be elucidated on these lines. Already it is known that the mitotic spindle and asters serve to elongate the cell prior to division, and that the power of a colloid system such as an aster, to imbibe water and swell, is governed by the ionic state of the medium. It is therefore of interest to find that salts which inhibit imbibition retard cell-division while those which promote imbibition accelerate cell-division. ([36])

Another example of successful application of physico-chemical concepts to embryology is Spek's analysis of the development of the egg of the worm Nereis. Injection of *p*H indicators shows a gradient along the egg-axis, the animal pole being alkaline and the vegetative acid, and this must involve a gradient of electrical potential. The rearrangement of the egg-contents which then takes place has all the appearance of a natural experiment in cataphoresis. Further, even after the equatorial cleavage divisions, the polarity persists and the animal end of the vegetative cells presents the alkaline reaction. It is remarkable therefore that the animal-pole portions of all these cells are constricted off as micromeres, which give rise to ectoderm, while the more acid vegetative-pole cells contribute endoderm.

These results lead on naturally to a consideration of *cytology*, in which subject there have been developed certain new methods and techniques for the study of the structure, function, and chemical nature of the cell and its constituents.

Tissue-culture and micro-cinematography have yielded most promising results, as in R. Canti's films and in J. Gray's studies on ciliary activity. (37) R. R. Bensley and I. Gersh (38) have elaborated the *freezing-drying* method of preparation, involving fixation in liquid air, with the object of avoiding alterations in the distribution of substances. R. Wurmser and L. Rapkine (39) have elaborated a micro-injection method for estimating the strength of the oxido-reduction systems in different parts of cells. H. M. Fox and H. Ramage (40) have applied a method of spectrography to various tissues with important results as to the location of various elements, showing in particular the universal presence of copper in protoplasm, while E. S. Horning and G. H. Scott (41) have developed the application of micro-incineration to Protozoa.

In *Protozoology*, interesting advances have been made by F. Gross, (42) who has found that the fluid contents of Noctiluca have a *p*H of the astonishing acid value of 3, and by H. M. Fox and H. G. Newth, (43) who have described a periodic process of swarming in Vorticella, apparently unconnected with reproduction or conjugation.

Cytological research has recently contributed greatly to *neurology*. In particular, C. C. Speidel's (44) and G. H. Parker and V. L. Paine's (45) investigations show that the nerve fibre is to be regarded not as a bundle of rigid fibrils, but as a fluid structure, capable of movement or peristalsis. This is of great interest in connexion with H. H. Dale's demonstration (46) of the release of acetyl choline from the endings of nerves through which impulses have passed, and G. H. Parker's views (47) concerning the part played by hormones or *neuro-humours* in nervous activity.

A very profitable new line of research was opened up by C. G. Coghill (48) in his parallel studies of the development of the nervous system in Amblystoma and the progress of the embryo's power of reacting to stimuli. In this way he was able to show anatomical correlates for the inception of new movements such as swimming, feeding, etc.

An important result of this work was the discovery that behaviour-reactions first affect the whole organism, and that local reflexes only become individualized later. The integration of behaviour thus antedates regional specialization of reactions.

This line of investigation has been extended to mammals by W. F. Windle, ([49]) and to birds by D. W. Orr and W. F. Windle. ([50]) While birds agree with Amphibia in the development of the behaviour patterns, mammals show a precocious specialization of local reaction, without evidence of initial total integration.

Much of course remains to be discovered regarding the structure of the nervous system in different animals, and notable contributions to this field are J. Z. Young's investigations in Cephalopod molluscs, and in Selachians. ([51])

Another line of inquiry, originating in studies of the swimming movements of fish, has established the existence of intrinsic rhythms in the central nervous system. ([52]) It is now known from E. D. Adrian and F. J. J. Buytendijk's work ([53]) that an intrinsic rhythm emanates from a respiratory centre in goldfish and W. D. le Mare ([54]) has shown how these rhythms are correlated, the swimming centre being concentrated in the medulla in Teleostei, but diffuse in the spinal cord in Selachii. The existence of intrinsic rhythms in the nervous system of invertebrates has been demonstrated by E. von Holst. ([55]) That certain sense-organs are spontaneously active has been demonstrated by H. Hoagland ([56]) for the lateral line in fishes, and by O. Löwenstein and A. Sand ([57]) for the semicircular canals of the fish labyrinth. The question of internal rhythms in general has been considered by I. von Stein-Beling. ([58]) It is also of great interest from the point of view of the control of breeding seasons, for J. R. Baker and I. Baker ([59]) showed that constant periodicity in reproduction still occurs in scarcely varying tropical climates.

Many of the results just referred to might have been included under the heading of *animal behaviour*.* A good example of the way in which neurological and physiological research can elucidate behaviour is given in J. Z. Young's ([60]) studies on the light-sensitivity of the lamprey. The tail is sensitive to light (the afferent path, curiously enough, being *via* the vagus lateral line nerve), and this stimulus initiates the swimming movement, which in the Ammocoete is forwards and downwards with the result that the animal

* See, further, the section on "Psychology," where the investigations of McDougall and his collaborators on the transmission of acquired characters in rats are described.

buries itself in the mud until it is in total darkness. The behaviour here therefore is a simple type of photokinesis, without any orientating effect such as is involved in higher types of behaviour, where directional (visual, auditory) stimuli initiate taxes.

C. L. Hull ([61]) has introduced what seems to be the very fruitful *goal-gradient* hypothesis, to account for the behaviour of an animal separated from a reward by a series of obstacles which it must "learn" to avoid. The excitation increases, apparently logarithmically, and changes in quality, with approach to the goal, and the possibility is given of an explanation from a fresh aspect of the phenomena studied by E. L. Thorndike. ([62]) The application of the "Gestalt" principle to learning has been considered by E. S. Russell. ([63])

As regards sensory perception, noteworthy synthetic surveys have been made by W. von Buddenbrock ([64]) on the function of the compound eye, and by O. Löwenstein ([65]) on the equilibrium function of the ear.

It is now clear from J. C. Faure's experiments ([66]) that the change in Locusts from the solitary to the gregarious and migratory structure and type of behaviour is controlled environmentally and not genetically; it can be brought about by overcrowding.

The behaviour and biological significance of the courtship activities of birds have been studied with great profit by W. Eliot Howard, ([67]) who has shown that the female passes through three sexual phases of behaviour. The onset of the fully-sexed phase appears to be correlated, as J. S. Huxley ([68]) has pointed out, with physiological changes preceding ovulation. Comparable changes appear to be concerned in the onset of the migratory habit in birds, and to be due, according to W. Rowan ([69]) to the increase in daylight in spring resulting in greater activity. On the other hand, T. H. Bissonnette ([70]) has found that changes in the gonad can be induced by light without increased exercise. Similarly, J. R. Baker and R. M. Ranson ([71]) have shown that in field-mice the onset of the breeding season is controlled by light acting on the gonad.

The analysis of sexual and social behaviour in mammals has been carried further in Primates by S. Zuckerman ([72]) who has studied them comparatively in relation to gonad activity.

Much interesting light has been thrown on phenomena of *growth* by J. S. Huxley's demonstration ([73]) that when a part or an organ grows relatively faster than the rest of the body, the differential growth-rate is constant over long periods. Such an organ is termed *heterogonic*. It is of interest to note that the mathematically predictable size of a heterogonic organ is a maximum limiting value which may be reached in different ways: thus the big claw of a male crab constantly adds to its size, but the antlers of a stag are shed every year, and it is a new antler which each year grows to the heterogonic size-limit corresponding to the size of the body. Not the least interesting of the results of the analysis of growth on these lines are the bearings which they have on other problems. J. Needham ([74]) has shown that the amount of various chemical substances present during development increases heterogonically. A species with a heterogonic organ and no finite adult size has no single "typical" finite form: an important consideration for systematists, as is the fact that many cases of dimorphism can be shown to be due not to genetic differences but to the existence of *equilibrium positions* for heterogonic organs. The phenomenon of "high" and "low" males in earwigs and beetles thus receives its explanation. The appearance of heterogonic organs independently in different stocks accompanying general increase in size provides a basis for the hypothesis of Orthogenesis often invoked to cover such evolutionary phenomena as the appearance of horns in different stocks of Titanotheres. (In future the term *allometry* is to be substituted for *heterogony*.)

Palaeontology has made great strides, thanks to the application of modern methods (especially W. J. Sollas's grinding and reconstructing method). D. M. S. Watson ([75]) has shown that the Arthrodira may at last be regarded as true fish, possessing proper jaws. E. A. Stensiö's work ([76]) even seems to indicate an affinity between Arthrodira and Elasmobranchii, while F. Broili ([77]) has shown that the structure of the Macropetalichthyids can readily be brought into line with that of Selachii. By elucidating the structure of Tarrasius J. A. Moy-Thomas ([78]) has made it still more probable that Polypterus is, as E. S. Goodrich suggested, ([79]) to be regarded as a Palaeoniscid, and not a Crossopterygian.

Of very great importance is the work of G. Säve-Söderbergh ([80]) on the Devonian Amphibia, the Ichthyostegalia. These remarkable animals had nostrils on the ventral side of the snout, lateral line canals in tubes piercing the bones, and a general arrangement of bones very similar to that of Osteolepid fish. Just as these Ichthyostegalia supply valuable information concerning the evolution of Tetrapoda from fish, so the Ictidosaurian reptiles described by R. Broom ([81]) show what the ancestor of mammals was like. In fact, the Ictidosauria might be regarded as mammals except that they retain the reptilian type of articulation of the jaws.

An interesting discovery among mammalian fossils is that of E. S. Riggs, ([82]) whose description of Thylacosmilus as a sort of "marsupial sabre-toothed tiger" adds another example to the parallelism between marsupial and placental mammals.

In *comparative anatomy* and *embryology*, recent work has shown two general tendencies. One of these has been the study by single investigators of particular structures in most or all the subdivisions of the groups of animals which possess them, resulting in monographs from which certain general conclusions and principles can be drawn. Among such works may be mentioned E. S. Goodrich's study ([83]) of the morphology of certain important structures throughout the vertebrates; J. P. Hill's investigations ([84]) into the placenta of primates; W. K. Gregory's study ([85]) of the bony skull throughout the fishes; R. Weil's investigations ([86]) into the structure and development of the nematocyst in all Coelenterates; and F. H. Edgeworth's collected researches ([87]) into the development of the cranial muscles in all vertebrates.

The other tendency shown by morphological studies is their close relation to experimental investigations. In this field important advances have been made in *insect physiology* ([88]) and in the problem of the *osmotic regulation* of animals ([89]) and especially of aquatic vertebrates ([90]). In the latter field, valuable results have been obtained by means of freezing-point determinations of the blood of fishes in water of different salinity, perfusion experiments, and morphological study of the kidneys and of the gills and of their chloride-secreting cells. The aglomerular condition of the

kidney in many marine Teleostei is seen to be correlated with the "difficulty" which the fish have in obtaining fresh water, which they have to "manufacture" from swallowed sea water by secreting the chloride out of it. Selachii have glomeruli, and the high urea concentration in their blood causes an endosmosis of "fresh" water through the gills, and this water can then be used for filtration through the kidneys. But the Selachian kidney also has a peculiar segment interposed in the renal tubule, and this serves to reabsorb urea back into the blood.

Another and excellent example of research involving both comparative and experimental methods is furnished by K. von Frisch's studies of the *senses* of various animals. It is now proved beyond all doubt ([91]) that fish, and especially the Ostariophysi, can hear. Further, the system of Weberian ossicles of these fish increases the sensitiveness of the perception of sound. Discrimination is good, and fish are capable of distinguishing between tones separated by an interval of a minor third. The sacculus and lagena are the seat of the sense of hearing, and it is noteworthy that in the fish there is no basilar membrane, the function of which in land vertebrates is probably discriminatory.

K. von Frisch's studies ([92]) on the senses and behaviour of the honey bee are classics.

The problem of *colour-change* has also yielded valuable results to experimental and morphological studies ([93]) and L. T. Hogben and D. Slome ([94]) have shown that the pigmentary system is controlled by hormones in Selachii and Amphibia. On the other hand, it seems that nervous integration plays a preponderating part in Teleostei and Reptilia. ([95]) Similarly, C. M. Yonge's studies ([96]) in comparative digestion have thrown light on the importance of the evolution of extra cellular digestion in connexion with the structure of the gut and the provision of digestive enzymes.

J. Gray ([97]) has investigated the mechanism of swimming in fish. The waves of curvature passing down the body bring it about that each point on the fish's side describes a figure of 8 movement, the leading surface pointing obliquely backwards, and this results in the forward propulsion of the fish. These experiments have also elucidated the functions of the various fins, thereby correcting many views previously held.

Altogether, experimental methods have recently shown good service in testing the validity of assumptions that various organs really perform the functions ascribed to them. A good example of the need for such work is provided by the so-called anal gills of mosquito larvae. Far from being respiratory organs, V. B. Wigglesworth ([98]) found that they serve to take in water, which is then used to flush out the Malpighian tubules.

The importance of these studies of physiological adaptation has been well stated by C. F. A. Pantin. ([99]) It is a striking fact as J. Needham ([100]) has shown, that the chemical form in which an embryo excretes nitrogen (ammonia, urea, uric acid) stands in relation to the condition in which the embryo has to perform the excretion. Such work naturally involves investigations which may be regarded as purely physiological, such as A. C. Redfield's reviews of the haemoglobins ([101]) and of the haemocyanins; ([102]) or J. Roche and H. M. Fox's work on chlorocruorin, ([103]) or J. Barcroft's comparative studies on the control of respiration in vertebrates. ([104]) Such work is, however, essential to zoological progress, not only in embryology as J. Needham's epoch-making survey shows, ([105]) but also in ecology, to which these considerations naturally lead. Thus, problems of the ecology of fresh water animals are being attacked experimentally in the laboratory by H. M. Fox ([106]) and R. S. A. Beauchamp ([107]) while the adaptation of marine animals to different latitudes is being studied by H. M. Fox. ([108])

In *Ecology*, Zoology links up with Botany, since as J. Phillips ([109]) showed, it is often necessary to work in terms of "biotic communities." A principle of great interest from the zoological point of view is that propounded by W. C. Allee ([110]) to the effect that undercrowding may be as lacking in stimulation to reproduction as overcrowding, and that there is a physiological optimum density of population. The phenomenon of variation and fluctuation in numbers in population has been studied by C. S. Elton, ([111]) who has pointed out its significance in connexion with migration, the periodic reduction in the rigorousness of natural selection, and animal inter-relationships. An important case of the latter is provided by "food-chains," the significance of which is well illustrated by A. C. Hardy and E. R. Gunther's

work ([112]) on the food supply of the southern whales, in which they demonstrate the puzzling inverse correlation between the phyto- and the zoo-plankton. Another aspect of inter-relationship is seen in the modern tendency ([113]) of expressing animal numbers in terms of total weight of animals per unit area of "biomass," which will ultimately make possible an estimate of total metabolic turn-over per unit area; and yet another principle is implicit in the discovery that the total number of species in animal communities so far investigated does not usually rise above a certain modest figure (excluding parasites). Ecology here touches the problem of evolution and species-formation. This is also apparent in C. S. Elton's principle of the selection of the environment *by* the animal. ([114]) As D. Lack ([115]) has shown, an explanation of the distribution of birds involves a psychological factor. Much more work is, however, needed on this point. Fortunately, in the very appropriate field of *Parasitology*, G. Salt ([116]) has shown that the problem of host-selection by parasites is amenable to scientific analysis. The female Chalcid Trichogramma selects a host for its eggs by its size, regardless of whether it be suitable or no.

Lastly, the theoretical aspects of Zoology have not been neglected of recent years. G. R. de Beer ([117]) showed that the relation of ontogenetic development to phylogenetic history could best be understood, not on Haeckel's view of the former being a "recapitulation" of the latter, but on the view that evolutionary novelties may occur at all stages of the life cycle, and not solely in the adult. The ease with which erroneous explanations can be given with the "help" of the recapitulation theory is well shown in the case of the nitrogenous excretion in bird embryos. In early stages this takes the form of ammonia, then of urea, and lastly of uric acid. Since invertebrates excrete ammonia, while fishes and amphibia excrete urea, it might seem that the bird embryo "recapitulated" the excretion of its ancestors. Actually, however, fishes and amphibia produce urea by an ornithine cycle, while the bird embryo produces urea by an arginine cycle. There is therefore no "recapitualation" here. ([118])

On the more metaphysical side, the implications of the concepts of "mechanism" and "vitalism" have been thoroughly explored by J. H. Woodger ([119]) and L. von

Bertalanffy. ([120]) Some authors, recoiling from either of these points of view, have been so impressed by the "wholeness" or co-ordination and organization of animals, as to regard these aspects as postulates. ([121]) On the other hand, it has been pointed out ([122]) that the wholeness and organization of organisms may be accessible to scientific analysis, especially now that X-rays confer the possibility of studying the composition of the *living* cell, and there is no more justification for the view that the technique of study kills living matter.

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VI

ANTHROPOLOGY

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THE subject-matter of anthropology embraces so many aspects of the nature and activities of man that it is possible to refer to only a few of the signposts that indicate the roads upon which progress is being made. In the following account much has been copied from many printed sources, and apologies are due to those authors who are not mentioned and for not giving definite references. The sole reason for these omissions is that the text would otherwise be overburdened.

Perhaps the most important recent generalization concerning prehistoric archaeology is that by Dr. O. Menghin and corroborated by l'Abbé Breuil, which postulates for early Palaeolithic times an essential contrast between stone implements made from flakes and those made from cores.

A predominantly flake-tool technique extended from North China to North-western France and the southern half of England in Lower Pleistocene times; the Icenian, Cromerian, and other cultures were mainly of this type. It is associated in Europe with a more or less arctic climate and fauna. In Western and Central Europe, the early flake-tools developed into the Clactonian culture, and parallel with this is the Levalloisian which extended into the Upper Pleistocene. Breuil has shown that the complex "Mousterian" of Europe was essentially a development of the Clactonian, but influenced Levalloisian and core-tool techniques.

Throughout Africa a core-tool, which developed from an earlier chipped pebble industry, is the oldest known technique; and the same applies to India. In Western Europe and the southern half of England hand-axes of progressive excellence of manufacture from Pre-chellean, through Acheulian to Micoquian, were associated with interglacial conditions and a fauna indicative of a temperate or warm

climate. We may therefore conclude that this culture spread from Africa to Europe.

These two main techniques overlapped to a varying degree throughout a very large area in Europe, but the flake-tool culture was more in evidence during the cold periods just as the core-tool was during the warm periods. There were various subsidiary cultures which do not concern us here. Progress does not seem to have been due to a simple process of evolution but to the interplay between various cultures, and this is mainly a functional or even a psychological problem.

There is little doubt that in some places the tools of the so-called "Mousterian" culture were made by members of the Neanderthal group of men, and there is evidence that in Palestine the makers of Levalloisian tools were of the same stock. In Europe there is no evidence of the type of man who made the core-tools, but Dr. L. S. B. Leakey has produced evidence which he maintains shows that core-tools in East Africa were made by men of the *Homo sapiens* type. In Kenya, at Kanam, he found fragments of a lower jaw which is admitted as belonging to *Homo sapiens* and possibly it was an ancestral form. The associated remains, which included stone tools, date the specimens as of Lower Pleistocene age, that is of approximately the same period as the Piltdown, and Peking men; very recently it has been shown that the Pithecanthropus of Java was of Middle Pleistocene age. At Kanjera he found fragments of two skulls of later date, but unquestionably of modern type, associated with Chellean implements. It had previously been suggested that some form of *Homo sapiens* had existed throughout the whole of the Pleistocene, and therefore core-tools might have been made by men of modern type. The discoveries announced by Leakey naturally aroused great interest and the matter was of such importance that it seemed advisable that they should be checked. Prof. P. G. H. Boswell went to investigate the two localities and found that there is doubt as to the stratigraphical horizons from which the remains were obtained and there is a possibility of disturbance of the beds; therefore he is of opinion that the geological age of the finds is uncertain. Thus apparently these specimens must temporarily be relegated to that unproven status that has

befallen so many other fossil skulls; Leakey however still adheres to the essential validity of his discoveries.

It is becoming quite clear that in early Pleistocene times there were several "genera" and more "species" of human beings, and the few that are known cannot be expected to represent all that were then existent. They had different conditions of life and doubtless made tools to suit their special needs with increasing dexterity, and the evidence points to the conclusion that each group tended to make tools that were more or less distinctive of that group. The mobility of man and his fertility in inter-breeding produced cultural complications which are slowly being unravelled.

There is no question that the Upper Palaeolithic and later cultures were the product of varieties of *Homo sapiens*. We do not know what caused the disappearance of the other types of men; it is purely a matter for speculation.

The prehistory of Africa is being unfolded by many workers who are breaking away from the traditional West European classification of stone implements and are drawing conclusions from their local material. The core-tool makers came into contact with makers of flake-tools of the Levalloisian type, and, as in Europe, "Mousterian" industries developed locally. The stone implements of various local cultures in South Africa are now being linked up with those of Tanganyika, Kenya, and Uganda, where the stratigraphical evidence is more complete than it has yet been found to be in the south. Correlation between the glacial and interglacial phases of the Ice Age of Europe and the pluvial and dry phases of Africa is being attempted which may be expected to supply a rough chronology for African prehistory.

There are indications that prehistoric climatic changes in India may be similarly equated with those of Europe. Very recent unpublished researches by T. T. Paterson in the Himalayan region of North-west India have provided a stratification of stone artifacts which should go a long way towards clearing up the sequence of the stone cultures of peninsular India.

Similarly in the extreme south-east of Asia, Dutch and French archaeologists have demonstrated a relative chronology for various stone cultures, and recent work in Indonesia

is revealing analogous cultures. Much more work requires to be done before a satisfactory synthesis can be arrived at, and it is not until this has been accomplished that we can expect a solution of various problems of the early history of Melanesia, New Guinea, and Australia. Extremely little has been done in archaeological stratigraphy in Australia; indeed it appears that not very much can be done in that continent.

The long progressive history of European civilization is being elucidated by archaeological discoveries in central Europe and the basin of the Danube.

Excavations in recent years have made known to us the cultural history of the great urban civilizations of Crete, Egypt, Mesopotamia, and North-west India, which were not self-contained civilizations, but were continually borrowing cultural elements the one from the other.

The geographical distribution of blood-groups has been studied extensively during recent years, and it opens out a new approach to the problem of the fundamental differences or resemblances of various peoples. When blood-transfusion was first practised it was found that the blood of all individuals was not compatible. In some cases the red blood corpuscles were clumped or agglutinated, with serious or even fatal results. This fact led to the demonstration that the blood of human beings falls into four groups which are the result of the interactions of three allelomorphic genes* usually called O, A, and B; O being recessive. The four blood groups are O, A, B, AB, and their genes are OO; AA, AO; BB, BO; and AB. In O there is an absence of the chemical substance which causes agglutination. The serum of A clumps the red corpuscles of B, as that of B does for the corpuscles of A.

* A gene is a discrete unit within a chromosome that transmits its own particular character, though its influence depends on all the other genes present. Each kind of gene may exist in a number of sub-types, or allelomorphs, which usually affect one and the same character in quantitative different or opposed ways. Two sub-types often differ from each other in being either recessive or dominant; thus, if the recessive gene exists side by side with the dominant, it exerts no visible effect on the appearance or behaviour of the individual, but though it is masked it is duly transmitted. A type may therefore be apparently pure but yet be impure in its composition. When both parents carry a recessive gene their offspring are likely to possess this gene in a double dose and then that recessive character becomes externally noticeable or functions actively.

There is a strong presumption that the primitive or original human type belonged to the O group and that at an early date A appeared as a mutation. The inference is that the New World was peopled from Asia before this mutation took place, for wherever among indigenous American natives, including the Eskimo, any other gene than O has been found it can be shown to be due to alien mixture. Peripheral peoples of the Old World, such as Australians, Bushmen of South Africa, and Lapps, have only O and A, except when they have acquired a low percentage of B through crossing with neighbouring peoples. There is a high percentage of group A in Western Europe which shades off to an intermediate percentage in Eastern Europe; but the A factor is not diagnostic of Western Europeans, since there is said to be a high percentage among the Armenians as there is among the native Australians. At a later date the B mutation appeared presumably in Asia; it is characteristic of Mongoloids and apparently also for the broad-headed Eurasiatics.

Serological differences, as far as is known, are entirely determined by Nature, and not by nurture; they depend on the substitution of single genes. They are absolutely clear-cut differences determined in the simplest possible genetical manner, and not appreciably subject to natural selection. For these reasons, in spite of all that has been said against them, they may be regarded, as J. B. S. Haldane points out, as one of the most promising fields of future research in physical anthropology.

At first it was hoped that the blood-groups would throw light upon the affinities of the main groups of mankind, but there is no correlation between blood-groups and the physical characters usually employed in the classification of human types. Human groups, ethnically and geographically widely separated, show considerable identity in their blood-groups and conversely human groups, ethnically and geographically closely related, do not show identity with regard to their blood-group percentage. It is evident that no one character, even that of blood-grouping, can form a sole basis for a classification of mankind.

It is accepted that blood-groups are inherited, that they remain stable throughout life, and that crossing with another

stock or stocks does effect a change in the distribution of blood-grouping. It has yet to be definitely proved, though it seems probable that there is a constancy of the proportions of blood-grouping in a population from generation to generation. If this be true, crossing would be the only method of altering the established percentage, but it has been assumed that first an A and then a B mutation arose. Could this have arisen more than once? Thomsen has described the existence of two A genes which, as Haldane says, may go far to explain anomalous differences found in certain racial groups. It has not been demonstrated that there is never any linkage involving blood-groups with other characters. The main problem to be solved is the actual manner in which the various different distributions arose.

The evidence points to the conclusion that Old World monkeys are more closely related serologically to man than they are to New World monkeys, and also to the evolutionary separation from the Old World primate stock of a group from which man and apes sprang. It is interesting to note that, so far as is known, the African apes, the gorilla and chimpanzee, belong to blood-groups O and A, while the Asiatic apes, the orang and the gibbons, belong to groups A, B, and AB. It thus appears that the B group arose as a mutation among the Asiatic apes, and the same seems to apply to Asiatic man. It is unknown how these differences within the groups of apes and men arose or what is their significance. Dr. S. Zuckerman points out that, as Osborne has emphasized, the descendants of a common ancestor would tend to develop along parallel lines if they were subjected to similar types of environment, since they began their evolutionary journey with similar potentialities. Consequently, structural similarities might denote nothing more than a descent from a common ancestor which may be quite remote.

Recent investigation on the hormones secreted by the endocrine glands has demonstrated their several influences on many anatomical characters and physiological functions, most of which are those wherein one ethnic group of mankind differs from another and it has been suggested that ethnic characters are determined largely by the activity of the hormones and that the inherited condition of the glands

provides a mechanism for the fixation of ethnic types. It must not be supposed that such groups as Mongols or Negroes are in any sense pathological, but merely that for one reason or another certain ductless glands function in some respects more actively, or less so, in these than in other groups. It remains to be shown what conditions of life or nutrition induce increased or decreased production of the hormones in question, or whether the conditions were "sports" which have been fixed by heredity. It has yet to be proved that these hormones are alone responsible for all ethnic differentiation, though they may well be contributory factors.

The ethnographical description of a people is apt to be of the nature of a static anatomy, which, though it has a definite value for anthropology, does not adequately present the concept of a living organism. Ethnologists in the United States of America have felt this need and have made various studies on the patterns of culture and the psychological interpretation of behaviour, which itself is mainly an expression of social control acting upon individuals. In this country the "functional" method of investigation regards a community as dynamic, every aspect of human needs and relationships reacts upon every other aspect, and working adjustments are arrived at with the object of promoting social stability, and thus a social structure is developed for those particular conditions. The dangers to be avoided are an undervaluation of objectivity and a bias of personal interpretation of the psychological processes implicated in these functionings.

It should always be borne in mind that nearly every human group is by no means strictly homogeneous and that in most there have been in the past various immigrations of culture-bearers of different ethnic stocks, achievement and mental traits, as well as of drifts of alien cultural elements, and these are still taking place. In the past, communities have had to make for themselves such adjustments as would ensure a system that worked with as little friction as possible, and it is this living mechanism which is now receiving the attention of many ethnologists.

The important changes that are taking place in all social organizations would be better understood and more wisely

directed if we had sufficient knowledge of their psychological causes. This generation has the greatest opportunity that has ever occurred of basing government and social organization on a sound psychological basis, so that the causes of strain and mental disturbance which in the past had led to so much harm could, in part at least, be avoided. There are no well-defined methods that could be blindly applied, but further psychological research on social problems is urgently needed. The small amount of real knowledge that has been acquired by modern methods of research in social psychology have proved of more value than the vague speculations that had preceded it. It is impossible to exclude psychology from any mental discipline or any study of social life, therefore there is urgent need for a consistent and generally approved body of psychological principles.

Typological psychology defines specific mental traits that characterize certain individuals, and it is now being investigated how far this terminology can be extended to groups of individuals irrespective of their size or to cultures. A cultural group may contain other types than the one which is diagnostic of the whole group, thus the men may have predominantly one psychological type and the women another.

Psychologists can be broadly grouped into those who are especially concerned with conscious behaviour, and those whose main interest is the unconscious driving forces of personality; to the anthropologist both of these aspects are of importance and need intensive investigation. As Dr. C. G. Seligman says: "Anthropology and psychology studied together may lead to a deeper understanding of the life of non-European peoples, as well as illuminate some hidden springs of human emotion and desire, so potent when the organism is subjected to excessive strain, though scarcely recognized in our daily lives of balanced thought and action."

While detailed investigations of the many discrete studies that collectively are termed anthropology will always have scientific value, there is increasing interest in the psychological interpretation of human conduct. At the same time there is arising a human ecology which, as Dr. J. W. Bews points out, is distinguished by its holistic outlook and technique and affords a scientific basis of criticism and evaluation

not only of man himself but of all his behaviour and all his works.

The unilinear conception of genetic stages of social evolution was a direct result of the influence of the biological theory of evolution and has been abandoned, though general trends in human evolution may be admitted. Sociological, as distinct from historical, schemes of development for the whole of mankind have been attempted, but none of them has been widely accepted. There is as yet no agreed classification on the basis of the economic or other level attained by various peoples, though this would be of value in helping towards an ultimate synthesis. Dr. M. Ginsberg points out that it has to be determined what elements in social life are functionally related and whether there are any regularities in the changes of institutions and whether the changes in any one institution are functionally correlated with changes in other institutions or aspects of social life. When a number of serial orders of change has been worked out for different aspects of social life, and is shown or assumed to be interrelated, a notion is obtained of a "general level" of a people's development, that is of stages or phases of its civilization as a whole. The establishment of associations between different aspects of social life or of correlation in sequence of change between them, does not in itself enable us to establish what are called "laws of development." The modification of social structure or institutions is rarely a simple phenomenon of internal development, for contacts with other cultures or with different complexes of cultural elements has always taken place. Ginsberg says that what is now urgently needed is further work towards the establishment of a more complete social morphology and more refined analysis of the complex life of social institutions, with the object of facilitating the task of comparison, and ultimately, of causal explanation.

Problems connected with the dynamics of population are receiving increasing attention and are discussed in the new international journal, *Population*. Such problems are very intricate and have a far-reaching significance.

It is essential to bear in mind, as J. B. S. Haldane points out, that biological success and economic success are very different matters and are not in general to be found in the

same individual. We know very little of what constitutes biological fitness in our particular economic system and we know nothing at all of what constitutes fitness in other systems. It has yet to be studied what characters assume a selective value when a primitive people is brought into contact with our type of civilization.

We do not know whether defects, greater or less fertility, intelligence, and the like are determined by one or more dominant or recessive genes. The full biological effects of differential fertility await further study, though differential fertility is being actively investigated by sociological methods, but this is a highly complicated problem and has led to opposing conclusions. Investigations are being made on the relation between diet and fertility and the importance of particular vitamins.

Statistics show that the birth-rate is higher among the poorer and less skilled in every class, so it appears necessary that there should be some well-considered policy in order to remedy this tendency towards deterioration. Urbanization and industrialization, as Dr. J. Rumney points out, are recognized as bringing about differential fertility, and everywhere cities have a lower birth-rate than the country. This may be partly due to the acceptance of birth-control in the more crowded areas or by the most thrifty persons, but this family limitation may depend to some extent on qualities socially undesirable.

The increase of mental defectives and of pathological stocks is relatively greater than that of the average normal stocks, but it is unlikely that the extreme types of defectives are reproducing disproportionately. Sterilization and other eugenic measures, however necessary, will not eliminate the need for institutional care, for many mental defectives can be trained to do useful manual work. There is no empirical evidence that racial deterioration is ensuing as a result of interference with natural selection.

The problem of the declining birth-rate is one which will have to be faced in the future, as there is a menace of underpopulation. It is obvious that the future welfare of mankind is bound up with these and allied problems, and their importance demands immediate investigation by social anthropologists of varied training.

Not many years ago it was scarcely realized that anthropology had a practical value in modern life; it was regarded as an unpractical and academic study. There were, however, a few who held that an adequate knowledge of anthropology combined with a sympathetic outlook was really of advantage for the administrator of alien peoples—as much for India as for Africa or Oceania. The Colonial Office is now fully aware of this and cadets for the African and Far Eastern services are required to have a certain amount of anthropological training. The time allowed for this instruction is too short to turn the students into trained anthropologists, nor indeed is this necessary or even perhaps desirable. What is needed is that they should have an ethnological sense and an appreciation of the rules of conduct, mode of thought, and the aspirations of the natives with whom they have to deal. The accumulation of such knowledge is usually more competently accomplished by trained observers who can give their whole time to it, and are not regarded by the natives with the suspicion which is always present when a Government official makes intimate inquiries. The information thus obtained is available for the administrator, who, prepared by the instruction he has acquired at a University, will be in a position to determine how far he can incorporate into administration the vital features of the researches of the specialist. The modern trends of ethnological study are especially important in this respect, and it is on such lines that anthropology may claim to take its place among the applied sciences.

VII

PSYCHOLOGY

By Professor J. C. Flugel, D.Sc.

A REPORT on the progress of psychology is an unusually difficult matter: in the first place because the frontiers of psychology are vast and ill-defined, coming into contact as they do with the most varied other disciplines, from philosophy, through a whole gamut of pure sciences, to the intensely practical concerns of the educator, physician, and industrialist: in the second place because present-day psychologists are divided into many schools, each with its own viewpoint, terminology, and technique. Amidst these widely varied fields and interests it is well-nigh impossible to tell the story in a way that will not seem to the future historian to be lacking alike in insight and proportion. The existence of so many schools and methods is evidence both of the complexity of the subject and of the activity and originality of the workers in it. Psychology is very much alive, but is suffering considerably from lack of integration. There are, however, signs that psychologists themselves are becoming more acutely aware of this deficiency. Alongside of books and articles written very definitely from the point of view of a particular school, there are beginning to appear textbooks dealing primarily with ascertained facts, and containing contributions from a number of authors of different theoretical persuasions: and, in addition, a few definite attempts are now being made to reveal the fundamental similarities of fact and theory which are so apt to pass unrecognized when viewed from different avenues of approach and described in a bewildering variety of terms. It is clear that such attempts are of the greatest value, and are essential to the consolidation of the results already won and to the further progress of the science upon a sound basis of—at least provisional—agreement.

As regards questions of fundamental biological importance, the investigation of most far-reaching import is perhaps that of McDougall and his collaborators (begun in 1920 and still

in progress) on the transmission of acquired characters in rats. He has trained these animals for many successive generations to escape from a tank by the more dimly illuminated of two exits, on pain of receiving an electric shock if they attempt the other exit. According to the latest report (1933), the average number of errors made by rats of the 30th–34th generations was 29, as against an average of 67 in the 13th–17th generations. The corresponding figures for the "best" rats are 2·6 and 32 respectively, for the "worst" rats 77 and 105. Unfortunately for the purpose of the experiment a considerable number of the "control" rats (untrained) also show improvement, presumably due to "some fortuitously favourable selection." Nevertheless of the several groups of control rats tested, no group gave an average of less than 102 errors, the "best" performers in the various groups ranging from 14 to 159 errors and the "worst" from 129 to 352 errors. In spite of the difficulty caused by the very great variation from rat to rat the figures are undoubtedly impressive and are calculated to reopen the Lamarckian controversy in an acute form.*

The study of mental heredity is notoriously full of pitfalls because of the difficulty of distinguishing between the influence of innate endowment and that of environment. Much evidence points to the conclusion that the ability measured by "intelligence tests" is primarily inherited, though here too there is perhaps a tendency, as the result of recent researches, to attach more importance to environmental influences than was the case a few years ago. Ever since Galton's pioneer work (taken up again by Thorndike in 1905), the investigation of twins has appeared attractive in this connexion. Quite a number of recent investigations show that pairs of like-sexed twins resemble one another more closely as regards their "intelligence quotient" than do unlike-sexed twins, while the correlation between the I.Q.'s of a series of pairs of identical or *monozygotic* twins approaches to unity. The general level and distribution of the I.Q.'s appears, however, to be much the same as in the population as a whole (though Gesell reports one pair, each member of which had an I.Q. of 183). We do not yet

* The subject of animal behaviour is further dealt with in the section on "Zoology."

possess correspondingly exact information on the side of character, though Lange maintains, on the basis of some figures collected by him, that there is a very strong tendency for criminality to be manifested, if at all, in both members of a monozygotic pair and in only one member of a dizygotic pair. In spite of these resemblances, however, it would appear likely that the mental similarity between monozygotic twins is slightly less than their anatomical similarity, a circumstance which has been held by some to show the influence of environmental factors upon mental measures such as the I.Q. Particularly important in this connexion would be the study of monozygotic twins reared apart. Very few such cases have been found, but in four such pairs investigated by Newman, the average difference between the I.Q. was about twice as large as that in the case of fifty pairs reared together. Evidence similarly pointing in the direction of environmental influence on the I.Q. has been obtained from siblings placed in foster homes, those in superior homes showing after a number of years a greater gain in I.Q. than those enjoying fewer advantages during the same period: though such studies, suggestive as they are, must still be accepted with caution, especially where linguistic tests are used.

Turning to the relation between intelligence and physique, there is fairly clear evidence for a low positive correlation between I.Q., height, and weight, in childhood. On the other hand, such factors as malnutrition, diseased tonsils, adenoids, defective teeth, seem to have little or no influence on intelligence. It looks as though, in general, mental development continues independently of physical influences and diseases, except those that directly affect the nervous system, and that the influence of environment on the I.Q., if genuine, must therefore depend on cultural factors. As evidence possibly pointing in the other direction, however, mention may be made of two researches which appear to indicate that a deficiency of vitamin B during infancy adversely affects the learning capacity of rats: as also of the investigation of Pintner and Forlano who, in studying over 17 000 cases, found a slightly lower I.Q. for children born in the winter months. Moreover, Kretchmer's views as to the correlation between skeletal build and type of mental

disorder seem to be receiving corroboration, the thin *leptosomes* being more liable to schizophrenia and the broader *pyknics* to manic-depressive insanity.

Although the main stream of psychological interest continues to be directed to individual differences and the study of the "higher" processes, rather than to the problems of sensation and perception, which received so much attention during the early days of experimental psychology, yet the absolute amount of work done in these latter fields continues to be large. In the field of sensation, amidst a great number of detailed additions to our knowledge which cannot here be mentioned, perhaps the matter of greatest fundamental interest is the claim (largely resulting from Katz's experiments) that there exists a vibratory sense which is quite distinct from ordinary tactual sensation. A tuning fork applied to the hand will give a definite sensation of "vibration" when the amplitude of the vibration is no more than 1/3000 of a millimetre, which, it is maintained, is far too small to give rise to a perception of tactual change. Vibration, moreover, behaves differently to touch, as regards local sensitivity (the tongue, for instance, is extremely sensitive to touch but relatively insensitive to vibration), fatiguability, adaptability, and latent time. The work of Gault seems to show that the vibratory sense may, with the help of suitable apparatus, be used as an aid to hearing in the deaf, who, by placing a finger upon a *teletactor*, are enabled to interpret the vibrations of a speaker's voice.

As regards perception, a great number of experiments continue to be carried out, especially from the "Gestalt" point of view. It becomes more and more clear that, as the Gestalt school maintains, perception must be explained rather as the result of the organizing power of forces operating in the mind at the moment than as the result of past experience, as the older "associationist" psychology supposed. Incidentally it may be noted that the most original general textbooks during the period under review come from members of this school. That of Koffka, in particular, appears likely to exercise an influence upon the future of psychology for many years to come. It constitutes a fitting monument to the zealous experimental work carried out by this school in its modern form for the last quarter of a century.

The dynamic interpretations of perceptual and other cognitive processes given by the Gestalt school bring the whole psychology of cognition nearer to that of conation and affection. It seems clear that the forces operative in perceptual organization must be ultimately of the same kind as those that manifest themselves in needs, instincts, emotions and desires. On a superficial view, it is true, the "stresses" of the Gestalt psychologists still seem to differ somewhat widely from the "instincts" of the hormic or the "libido" of the psycho-analytic schools. And yet the same tendency to entropy, equilibrium, least effort (call it what we will), is surely manifest both in Wertheimer's "Law of Prägnanz," according to which "psychological organization will always be as 'good' as the prevailing conditions allow" and Freud's "Death Instinct," according to which "the goal of life is death." One of the most important tasks of the psychology of the near future will be to clarify the underlying elements of unity between apparently divergent formulas of this description.

Among the problems of sensation and perception that are arousing greatest interest at the moment are the "constancies" of size, shape, brightness, and colour. It is here that psychologists are beginning to realize that in spite of all the work done on visual sensation in the past, the orientation of research has been unduly biased in the direction of physiology, with the result that a whole set of distinctively psychological problems has been neglected. We tend to see a round table as round, whatever the nature of the image it may form upon the retina; a shadowed white surface is, under ordinary conditions, easily distinguished from a more brightly illuminated grey one, though the two surfaces may be photometrically equal. Strictly speaking, indeed, the "sensations," about which so much has been written, are no true facts of experience, and to understand what we actually see (as distinct from the physiological impressions received) we have to learn to contemplate our experiences with the requisite *naïveté*. We then find very often that our crude experience corresponds much more with the "real" objects seen than with the way in which they happen to affect our sense organs. This approximation of our perceptions to reality has been called *phenomenal regression*, and

the degree of this regression has been found to differ according to individuality, age, and even race. There is some evidence that, in general, phenomenal regression tends to increase with age, both in adults and in children, but that it correlates negatively with intelligence. Women, it would appear, show rather more phenomenal regression than do men of the same age and intelligence, and the same is true of Indian and West African students as compared with British students. While it would be dangerous at present to generalize from such results it is evident that they open up a vast new field for further research.

At the opposite pole (in certain respects) to the Gestalt school is the behaviourist school, whose especial contribution to method has been the study of the conditioned reflex. The application of this method to human beings is still somewhat limited (though, as an indication of its promise in novel directions, may be mentioned an experiment in which it has proved possible to evoke conditioned reflexes in response to subliminal stimuli): but it has by now been used successfully with a great many animals, even as low as infusoria. From these researches it would appear that the speed of conditioning measured by the number of combinations (of the conditioning and the conditional stimulus) required for the first appearance of the conditioned reflex does not become *consistently* greater with ascent of the organism in the evolutionary scale: for instance the speed in fish and frogs does not appreciably differ from that in dogs, monkeys, and children. It is, however, slow in infusoria, crustacea, and cephalopoda: while there is pretty good evidence that it is slower in mentally retarded dogs and children than in corresponding normal individuals. After its first appearance, a conditioned reflex usually passes through a transition period of instability (characterized by irregularity of appearance and relatively small response), so that both its first appearance and its final stabilization must be studied. Evidence as to the nature and degree of correlation between speed of conditioning and of subsequent unconditioning is in general still somewhat conflicting, though it would appear that the correlation is positive in the case of children. One of the most curious and interesting applications of the conditioned reflex method has consisted in the

attempt to produce immunity to certain diseases. A considerable number of animals, including guinea pigs, horses, and human beings, have been used in such experiments. The conditioning stimulus consists of an injection of antitoxin, while the conditioned stimulus may take any of the usual forms (warming or scratching the skin or blowing a horn have actually been used). In some cases there appears to have been success in establishing a conditioned leucocytosis, animals injected with mortal doses of various disease germs surviving when the injection was preceded at a suitable interval by the conditioned stimulus (without the antitoxin), while others, similarly treated and generally conditioned except for the absence of the preceding conditioned stimulus, succumbed. In other cases the establishment of immunity was inferred on the basis of leucocytic counts.

Perhaps the most significant work on animals by other methods has been concerned with "needs" or "drives" and with social behaviour. Various procedures have been devised for measuring the strength of drives (in the case for instance of hunger or sex), such as the establishment of a "preference list" of foods or sexual objects. When the drive is strong the animal will satisfy himself with an object lower on the list than that which will appeal to him when his desire is less urgent. By means of this and similar procedures Katz and other investigators have established certain parallelisms between hunger and sex, such as daily rhythms, increase of appetite after abstinence, increase when the variety and extent of opportunity is augmented (e.g. the animal eats more when several different foods are available), "oversatisfaction" producing temporary satiation with even a preferred food or sexual object, diminution of appetite through the thwarting of other needs, etc. Further researches have shown the stimulation of appetite through the administration of appropriate glandular substances.

Among works on the social psychology of animals, mention should be made especially of Zuckerman's observations on the behaviour of the inhabitants of Monkey Hill in the London Zoo. He revealed the existence of a sort of patriarchal society, with a number of "overlords," each dominating his own circle of females, children and "bachelor" males.

To some readers his descriptions have seemed irresistibly suggestive of the Darwin-Atkinson-Freud reconstruction of primitive human society, while his accounts of simian sexuality also seem to fit in well with the observations and theories of Freud. There can be little doubt that similar long-period studies of social behaviour will play an increasingly important part in the animal psychology of the future.

The processes of learning, retention, and forgetting continue to engage the attention of psychologists. Particular interest has perhaps been devoted to the subject of the variation of ability and learning powers at adult ages. From recent studies (especially those of Thorndike) there is now quite a considerable weight of evidence that the power of learning (especially perhaps learning of the more mechanical kind) declines from about the twentieth year onwards. On the other hand, a small-scale but suggestive experiment by Burtt illustrates the retention of early childhood memory traces. Selections from Greek drama were read to a boy at various times between 15 months and 3 years of age. When these and other comparable passages were subsequently learnt at the age of $8\frac{1}{2}$ years, there was a great saving on the passages already heard. Researches continue to be made also on the subject of "retroactive inhibition," i.e. on the tendency of subsequent mental activities to "wipe out" the effects of previous learning. As a result of these studies it now appears fairly safe to assert that some retroactive inhibition occurs at all temporal positions of the interpolated activity (between the original learning and the recall). Forgetting, indeed, appears to be to some considerable extent a function of the interpolated experience. It is still doubtful whether the effect is always greatest when the activity *immediately* follows the learning, as had sometimes been supposed. Experiment has shown, however, that comparatively long periods of sleep (as distinct from short periods of, say, one hour) following soon after the learning, have a beneficial effect upon retention—so that study at night may sometimes more than gain in retention what it may lack in learning capacity through being carried out in a state of relative fatigue. As regards the dependence of retroactive inhibition upon the nature of the interpolated activity and its relation to the original learning activity, there is, on the whole,

corroboration of the earlier findings that the closer the similarity of the two activities (up to a point approaching identity in some or all of the elements), the greater the "wiping out" effect.

Interesting experiments in a somewhat neglected field have been carried out by Bartlett, who caused a story or report to be repeated by one individual to another, by this latter to a third, and so on through a long series of subjects, noting the changes that took place *en route*. These changes were in some cases even more astonishing than we might have expected from our general knowledge of the vagaries of rumour and they reveal clearly the *active* elements involved in assimilation and recall.

In the field of work and practice effects perhaps the two chief events are: (1) the demonstration by Philpott that the fluctuations of the work curve are not, as most previous investigators had supposed, of approximately constant duration, but tend to increase in length proportionally to the logarithm of the time, the actual curve obtained on any occasion being explicable on the assumption that it contains a selection from a large number of elementary waves, no one of which is specific to any person, task or condition; (2) Mace's study of the incentives provided by the nature of the work itself, showing that a standard that is too high or too low decreases effort and output, and that the standard can profitably be varied as practice improves performance.

The "factor school," which owes its origin to Spearman, continues to inspire a multitude of researches. While the existence of "g" has been amply corroborated, the discovery of several new factors has been claimed, notably "v" (a *verbal* factor), "f" (a speed or *fluency* factor), and a *routine manual factor* (distinct from the already discovered "m," which is a factor concerned with the understanding of mechanisms rather than with direct manipulative ability). "P" is being much discussed in both its practical and theoretical implications, Pinard and Cattell having both shown that its (negative) correlation with "w" (Webb's factor of *persistence of motives*) is not linear, but that individuals of "difficult" character tend to give unusually high or unusually low "p" scores. Quite recently the methods of correlation so largely used by the factor school have been applied by

Stephenson in a new direction, namely to correlation of individuals instead of tests. Such evidence as he has brought forward makes it appear likely that this will prove a potent method for the investigation of "types."

As regards mental testing in general there has been an increasing tendency to carry out very large surveys in given geographical areas. Thus in New York, Blackburn, and Bath there have been city-wide studies of the children between certain ages or in a certain grade. In the last-named town a very special effort was made (in view of the proved difficulty of obtaining an adequate random sample) to test *all* the children concerned. The most imposing work of this description, however, was the survey of 87 498 children between the ages of $10\frac{1}{2}$ and $11\frac{1}{2}$ carried out by the Scottish Council for Research in Education, this being the first time that there has been obtained a cross-section of the intelligence of a whole nation. A group verbal test was employed, the relation of which to the Binet test was obtained by using a sample of 1 000 cases on both tests. As judged in this way, the average I.Q. was almost exactly 100 for both boys and girls, though boys proved themselves very slightly more variable than girls, thus confirming a result often suspected and already found in many minor researches.

In America, especially, there have been numerous investigations on the side of character and "attitude" and a variety of new techniques has been devised. The results obtained are difficult to summarize and are as yet of such a nature as scarcely to permit of generalized conclusions. To quote from a recent review: "Perhaps the most outstanding impression is the spotty nature of the experimental data in social psychology. It is literally strewn with odds and ends of experiments. . . . Another striking fact is that so few experiments are repeated by other investigators. That which is so common in the physical sciences rarely happens in the social sciences. The result is an increasing accumulation of unverified data." This is not to say that some of the results already obtained will not eventually prove to have great significance.

Several important developments have taken place in the work undertaken or inspired by the psycho-analytic school. The special play technique for the psycho-analysis of young

children developed by Klein and the detailed observations on the social behaviour of children by Isaacs have brought valuable fresh light upon the formation of the "super-ego" (or moral factor), the harshness of which appears to be largely due to an introjection of the child's own aggressivity. On the anthropological side, Róheim's field studies are the first of their kind to be carried out by a psycho-analytically trained investigator, while Seligman in his recent work has adopted the psycho-analytic point of view far more wholeheartedly than any other anthropologist of comparable standing. Unwin, from a most extensive review of the available data concerning sex behaviour and certain cultural institutions among many peoples, has produced evidence of an astonishingly complete inverse correlation between the development of these institutions and the prevailing degree of sexual freedom. Alexander, at the Chicago Institute for Psycho-analysis, has inspired valuable team work in the simultaneous analysis of a considerable number of comparable cases. In dealing with the results obtained, he has suggested a new "vector analysis" of psychic tendencies, human impulses being classified according to the three fundamental "directions" of "incorporation," "elimination," and "retention" (each of which has two sub-groups roughly corresponding to love and hate). Finally there are signs that experimental psychologists are attempting to test psycho-analytic conclusions by their own methods, interesting experiments having appeared on such subjects as "autistic" gestures, "projection" on to others of an individual's own defects, "introjection" or the turning against himself of his own aggression, and the effect of wounded self-esteem upon the process of forgetting.

The subject of hypnotism, after long neglect, is now at last receiving more adequate treatment, especially at the hands of Clark Hull and his collaborators. In general, the differences between the hypnotic and the normal state appear to be quantitative rather than qualitative in nature, while such differences as are found seem to be due to heightened suggestibility rather than to any essential character of the hypnotic state as such. The views long ago propounded by the Nancy school have thus received verification by far more exact methods than any hitherto employed. At the

same time the experimental post-hypnotic production of short period neurotic disturbances by Luria and others opens up a new and possibly very valuable method for the detailed study of the general processes involved in functional nervous disorders.

VIII

EDUCATIONAL SCIENCE

By A. Gray Jones, M.A., B.Litt.

PERHAPS no science has a more intimate relation with the life of the community than educational science. This is the case whether we are concerned with the philosophic background or with the experimental work that is the necessary accompaniment of every science. Thus an account of recent developments in educational science will be found to emphasize the influence on education of changes in the structure of society.

During the quinquennium 1931–1935 the most notable developments have been, not in research, but in the reconsideration of principles, the re-examination of methods and the application of mechanical aids. There is no major advance to report, but there has been a shifting of emphasis. It is proposed in this survey to deal in succession with recent trends of educational thought, to note developments in educational research, to describe the application of mechanical aids such as the cinema and broadcasting, and to refer to recent inquiries into the teaching of science, the value of examinations and the increased importance given to physical education.

RECENT TRENDS IN EDUCATIONAL THOUGHT

A discussion of recent trends of educational thought must of necessity note the impact on educational science of events in the wider world. Educational science deals with human material: the aim of education is the development of a full human personality and the cultivation of a many-sided interest, and in the fulfilment of that aim a continuous alteration of emphasis is effected by changes in the life of the community.

Two of the major influences that have dominated the life of the community since 1930 are firstly the economic crisis that came to a head in Great Britain in August-September, 1931, and secondly, the rapid growth of the totalitarian

state in Europe with its threat to all liberty of thought and freedom in education. No study of recent trends in educational science can ignore these two factors.

Other influences are also working, such as the suburbanization of large parts of the country, the advance of mass-production and rationalization in industry, the decay of communal life in large towns, the brightness and efficiency of the new homes and the new schools, while it is a truism to say that the film, the radio, and the internal combustion engine have both spanned and contracted the modern world.

In this way we have been forced in recent years to reconsider the purpose and method of educational science. How far if at all should education be vocational? Can the concept of the individual be preserved in the modern world? Is the education given in our schools sufficiently practical? Is it too academic and too specialized? Can mechanical aids to education be usefully employed? Are examinations an adequate criterion of achievement? Can education be full and creative if it neglects the physical?

Education and the Social Crisis

The changes in the economic structure of modern society have not yet stabilized and are accompanied by hardship to masses of citizens in Britain as elsewhere. Rationalization, mechanization, the imperfect adjustment of production to distribution, have dislocated occupational life, and, as Schairer has shown, have led to a replanning of our system of public education and a reinforcement of school education by out-of-school activities.

The rapid development of the educational system since the War has brought higher education to a far wider range of students. The aim is more and better education for as many as possible. This increased activity stimulates greater activity among the students which sometimes, in some countries, has explosive results. The trend is ever towards the professions and distributive trades and away from the crafts. But the professions are becoming overcrowded: already in South Wales in 1936 a hitherto unknown phenomenon has appeared—the foundation of "unemployed graduates" associations at Swansea and Neath.

Moreover, independence and creative activity, possible

in the crafts, is disappearing: the machine is dominant and the industrial combine is killing individuality in production. Confidence in life and pride in a vocation are no longer possible for the vast majority of citizens, and there is a weakening of community life in towns through the development of modern transport.

Education has tried to meet the social crisis in various ways. Thus the unemployed juveniles are being provided for by junior instruction centres (whose work was thoroughly surveyed in 1934 by Valentine Bell). The adult unemployed in the distressed areas are now helped by social service centres where crafts are taught and cultural activities such as music and the drama find a place. This work has developed considerably since 1932, but it can at best be only a palliative for those who have no share in productive activities based on a reasonably secure economic order. The new community centres founded in satellite towns like Dagenham are a gallant attempt to meet an urgent need: whether they are not somewhat artificial in their nature is at least arguable. Even the large-scale planning of technical education announced in December, 1935, may arouse doubts: is the purpose of this development to provide more efficient cogs in a vast machine controlled by a few super-men?

The final purpose of education is surely the full development of human personality, and educational science must serve that purpose. When, therefore, society does not provide adequate opportunity for developing human personality, educational science is circumscribed and unable to function with full efficiency. Hence a certain uneasiness and dissatisfaction that is felt by educationists: it may be that their doubts should not discourage them unduly, for over fifty years ago Matthew Arnold was perturbed by—

> . . . this strange disease of modern life
> With its sick hurry, its divided aims,
> Its heads o'ertax'd, its palsied hearts,—

and since then we have, somehow, surmounted crises far graver than he conceived.

Education and Freedom

A more cheerful trend in educational thought is our revived passion for freedom, our conviction that the liberties

of our country depend on free discussion. Our primary schools had been emerging before 1914 from the grip of rigid formalism. The wisdom of our national tradition which abhors precise regulation and leaves as much scope as possible to local initiative has enabled our secondary schools to display a diversity of experiment not possible in countries like France and Germany, where education is centralized. The Hadow Report of 1927 showed that our belief in freedom to experiment was as strong as ever, and the growth of our new senior and central schools since 1929, when the Report began to be implemented, with their diversity of courses untramelled by examinations, shows most hopeful features. The examination system that dominates our secondary schools has concurrently come in for severe scrutiny and sooner or later they must recover their freedom, in all that concerns the curriculum, by wise readjustments within the examination system and a saner attitude on the part of employers and the public towards the value to be placed on the judgment of any examination.

The revival of autocracy in Europe and the disappearance of liberty over large areas of the Continent has once more reminded us that the British tradition of education should be based on freedom. Our reaction to dictatorships is an appreciation of such freedom as we possess in British education and a searching review of any factors that may imperil that freedom. We realize anew that society exists for the sake of personality and not personality for the sake of society. We must recognize that while society moulds the human type, the true value of personality comes from development beyond the type. But while we encourage freedom we must remember how it is aided by security. In our island we are more fortunately placed than continental states and thus there lies on us a special responsibility. Yet we must face the fact that our era of industrial supremacy with its accompanying economic security is over, and we cannot yet regard war as a thing of the past. Appropriately enough the most recent educational association to be founded in 1936 is the National Council for the Teaching of International Relations.

Educational Research

During the period under review a certain amount of research in education has been conducted in various directions. There has, however, been no general co-ordination of the results achieved, except in the case of research on examinations, and a good deal of the isolated work of individual students remains in manuscript form, such as unpublished theses for higher degrees.

The need for the comprehensive planning of research in education has long been felt: in such matters the United States is ahead of us, as is instanced by the pioneer American work on intelligence tests. While English educationists may perhaps not wish to emulate the exhaustive and large-scale methods of, for example, the Teachers College of Columbia University, nevertheless there has developed a general feeling that in this country we ought to be able to co-ordinate research more adequately.

Several schemes for developing research have been discussed in recent years. The latest was the abortive attempt of the Royal Society of Teachers in 1935 to found a Research Council: it is possible that a further united effort on the part of the universities, teachers' organizations, and local education authorities may be more successful. In this connexion it may be noted that the former London Day Training College was refounded in 1932 as the Institute of Education, and is to move in 1937 to commodious premises in the new buildings of London University. The Institute has the opportunity of developing further activities, for example, as a centre of Empire education and a bureau of information: it may conceivably house a future national library of education; and clearly, if educational research is to be co-ordinated on a national scale, the Institute, situated in the heart of London, will be in an exceptional position to join with other universities in such a development.

The Scottish Council for Research in Education

Meanwhile, Scotland has already indicated one way in which educational research can be organized. Founded in June, 1928, the Council includes representatives of universities, training colleges, school medical officers, and psycho-

logists. Its investigations include, since 1930, research on standard tests for the Qualifying Examination in Scotland, the curriculum for pupils of ages 12 to 15, secondary school pupils' attainments, environmental influence on mentality, mental surveys of rural and urban areas, visual aids, and the value of university entrance examinations.

Research indicates that Scottish intelligence is more evenly distributed between urban and rural areas than it is in England and Wales. Mental deficiency was less (1·5 per cent) than the figures arrived at by E. O. Lewis in 1929 for England and Wales—3 per cent urban, 6 per cent rural areas. Comparisons between American and Scottish pupils of equivalent "grades" on the basis of a test in the schools of Fife indicate a marked superiority in the intelligence and attainments of Scottish children.* The Mental Survey of Scottish Children (a group test for 9 000 pupils undertaken in 1932), showed that the increased opportunities for university education have not resulted in a lowering of university standards. The amount of high intelligence in the community is greater than had been previously assumed, and this raises the social problem of how this intelligence can best be used by absorbing it in employment affording reasonable scope for such abilities.

Formal Training

Mention may conveniently be made here of a report published in 1930 by the British Association: this was the work of a committee appointed by Section L (Educational Science) to consider "The bearing on school work of recent views on Formal Training." The report may be regarded as an authoritative statement of the disciplinary value of various elements in the curricula of the schools, about which much confusion of thought exists. Subjects of relatively little importance are often given an excessive amount of study with the object of securing a mental discipline for which they are alleged to possess special qualifications. This doctrine, that the study of such subjects "transfers" a special capacity to the pupil for the acquisition of other subjects, has been widely criticized during the last quarter

* See *The Intelligence of Scottish Children*, 1933, University of London Press. *Achievement Tests in the Primary School*, 1935.

of a century and the Committee's report moderately supports that criticism.

Papers by Burt, Cavanagh, Arnold, and Pear show that conscious or deliberate transfer is more frequent and useful than passive or unconscious transfer: sound training comes not from the mere perception of facts but the perception of relations between facts. The intelligent child, if led to recognize clearly the methods by which he can achieve efficient work, will gain a definite amount of transfer. Thus the educative value of a subject does not reside in the subject itself but in the way in which it is studied. Hence an extreme emphasis on examinations is a danger since examinations tend to encourage cramming and spoon-feeding rather than a genuine interest in a subject and thus a conscious knowledge of sound method. Moreover, the emotional attitude greatly assists such transfer as takes place; the liking for a certain subject or for the particular teacher or for his method are powerful vehicles of transfer.

Mechanical Aids to Education

(1) *Visual Aids*

Visual aids include the lantern with slides and the cinematograph. The former has for more than a quarter of a century been a useful auxiliary in the teaching of history, geography, and science: a similar device, the epidiascope, for the projection of reflected images such as diagrams and photographs has been greatly improved in the last ten years through the production of better lenses and more efficient lighting. But the chief development in visual aids during this quinquennium has been in the educational film. Experiments in the use of films for teaching purposes have a long history; the writer attended a geography lesson illustrated by a film as long ago as 1908—but it is only since 1929 that educational films have been the subject of continuous study and experiment, and in 1936 we are witnessing the fruits of this work in a systematic production and circulation of educational films and a seasoned appreciation of their possibilities.

A Committee of the Imperial Education Conference of 1923 had reported favourably on the use of the cinemato-

graph in education, and in 1929 the League of Nations published an Educational Survey on the use of films. On the Continent, particularly in Italy, films were coming to be used in schools and an "International Review of Education Cinematography" was published monthly at Rome.

A Committee of the British Association inquired in 1928–9 into the production and distribution of educational and documentary films, and reported that the case for the use of films in education was still a *prima facie* one. Little headway had been made in the schools, for few suitable films had been produced, and the technique of their use in the classroom was not known. The Committee recommended a "non-flam" film, preferably of 16 mm. size, with a base of cellulose acetate. Detailed specifications of a 16 mm. projector were given. Suitable types of screen were recommended, and also measures to avoid eye-strain and minimize risks of fire or accident. These recommendations have subsequently been generally endorsed. The Committee suggested that a Commission on Educational and Cultural Films should be established to stimulate public interest, and this commission was formed in 1929.

In its report on "The Film in National Life" (1932) the Commission recommended the formation of a permanent institute for promoting co-operation between those who make, distribute, and exhibit films and those who are interested in their artistic, educational, and cultural possibilities.

The British Film Institute was founded in 1933 to carry out these aims, and a prominent part of its work has been to foster the use of educational films, through its educational panels, through its quarterly, *Sight and Sound*, which devotes a special place to suggestions for teachers, and through its reviews of educational films in a Monthly Film Bulletin. The Institute has at last achieved a much needed collaboration between film producer and teacher, a typical result of which is the excellent series of films on physical education produced in 1934–5.

By now a widespread interest in educational films has been aroused, and the supply of suitable films is increasing. The Board of Education gives grants for the purchase of film apparatus (50 per cent in secondary and 20 per cent in

primary schools) and many new schools are equipped with lecture halls and projectors, capable of showing both silent and sound films. Incidentally the general introduction of sound films since 1929 has not led to the silent film being ousted. The relative value of both types is now judged according to the purpose for which they are used.

Here we must distinguish between "foreground" and "background" films. The former are an auxiliary to the classroom lesson in the same way as the blackboard or diagrams or chemical apparatus. They form part of the lesson: their purpose is instructional, to assist in imparting information, and experience shows that ten minutes is the maximum length for such films. Most teachers find that silent films are the best for instructional purposes: biological films are a good example of this type.

Background films usually deal with subjects outside the curriculum: their purpose is to broaden the pupils' ideas and to impart cultural knowledge as opposed to information. Good examples of this type are travel films and films with a wide human appeal, such as the admirable "Drifters," produced by Grierson for the former Empire Marketing Board. Sound films are usually preferred for this purpose and their length may extend to twenty minutes.

Various experiments in the use of educational films have been conducted in recent years. Pioneer work in producing films at school with the aid of the pupils has been done by R. Gow at Altrincham and W. H. George at Chesterfield. In Middlesex in 1931 a large-scale experiment on the use of sound films in secondary and primary schools was perhaps more useful for propaganda purposes than for any clear conclusions. The value of historical films was investigated in 1931 by F. Consitt. A recent experiment under the L.C.C. (St. Pancras, 1935) has endeavoured to elicit the responses of children to various categories of films. Perhaps the most notable experiment was conducted by the Glasgow L.E.A. in 1933: retentivity tests were applied to five groups of three classes each with favourable results on the whole: not surprisingly it was noted that in the hands of certain teachers the film is an advantage. So here as in everything else the teacher is the corner-stone of educative processes.

Much progress has therefore been made since 1930, but

research into the use and value of educational films is only beginning. For example, it has yet to be decided by experiment how film instruction can be adapted to pupils of different age groups, and how far images of particular scenes can help or hinder imagination and whether visualization can assist in the building up of concepts. At the present moment subcommittees of the Film Institute are preparing reports as to the contributions that educational films can make to the teaching of modern languages, history, science, or other subjects of the curriculum.

(2) *Aural Aids*

The recent development of aural aids to education has been more rapid than that of visual aids; the main reason for this is the fact that the chief form of aural aid—school broadcasting—was introduced by a corporation (the B.B.C.) with considerable resources and a monopoly of the field, but a strong sense of social responsibility.

The gramophone was beginning to be used sporadically about 1922 for the teaching of languages and music, and some excellent courses in musical appreciation were devised by Percy Scholes in 1923–6. Just when the gramophone was being widely introduced school broadcasting began (in 1924) and from then the gramophone was slowly but inevitably restricted to its proper function in schools, i.e. for repetitive work. Although electrical recording and improved amplification were introduced about 1927, one great disadvantage of the gramophone has not been overcome, for only a limited amount of material can be recorded on a disc. Moreover, the gramophone is a purely mechanical aid; its use will be further restricted by the general introduction of sound films, and the limits of its utility in schools have been reached.

School broadcasting has been developed on a very large scale since September, 1924, when the first regular series of school broadcasts began. By August, 1926, nearly 2 000 schools were taking broadcast lessons, and in 1927 a special experiment was carried out in Kent, with the co-operation of the Education Committee, to discover whether school broadcasting could and should be further extended. This experiment demonstrated the necessity for establishing a

central body for methodical research, organized on a representative basis. The period 1924–9 was thus one of experiment and pioneer work.

In 1929 the B.B.C. was given large autonomous powers, and simultaneously a Central Council for School Broadcasting was established, and a complete and co-ordinated series of courses devised with the aid of subject panels of teachers and experts. In 1935 the Council's activities were reorganized and the work of the "listening-end" separated from that of the programme department. The need of special attention to method has been recognized and programmes will henceforth be more closely supervised in that respect.

School broadcasting was thus put on its feet in the quinquennium 1930–1935, but considerable ground for expansion remains, since only a seventh of our schools are taking broadcasts at present. The chief hindrance was lack of good reception due in part to inadequate standardization of good cheap sets. Moreover, Education Authorities are still reluctant to find the large sums required to install sets in all schools. Teachers have not always taken kindly to this new educational method and were at first discouraged by the faults in the presentation and content of material that were inevitable in the experimental stage. Nevertheless with good reception and well-planned and methodically presented material, school broadcasting can be a valuable ally, stimulating the child's imagination and introducing him to new horizons, particularly in the talks on history, music, geography, and current affairs. In the teaching of modern languages it has a different but very valuable contribution to make.

Attempts are being made to examine objectively the value of school broadcasting. The Board of Education, through its inspectors, have been gathering much information, but this has not yet been analysed. In an interesting study by F. J. Schonell* its purely supplementary nature is emphasized. He found by group tests in a senior school that it has certain vitalizing effects, that careful preparation by the teacher and thorough revision are necessary, that illustrative diagrams and pictures have a high utility value, that note-

* *British Journal of Educational Psychology*, November, 1935.

taking is a hindrance and that matters of considerable importance to the pupil are factors of emotional stability, general verbal power, and general intelligence.

Considerable progress may be expected in the use of broadcasting in schools; it has hitherto been developed with courage and initiative. Wisely used it can be of considerable value. But in the last resort education depends largely on the personality and knowledge of the teacher, to whose work broadcasting can at best be but a supplement.

It remains to be noted that the next developments will include experiments in television. When that arrives, broadcasting and the film will converge in a new aid of hitherto unknown possibilities.

The Teaching of Science

For the last twenty years there has been a growing conviction that science is taught in many schools on too narrow a basis and with an insufficiently broad outlook. Those who hold this view believe that science cannot be effectively taught through sciences rigidly divided from one another; thus they hold that a boy may pass through his School Certificate Examination with credit in chemistry, physics or biology and yet be unaware of the fundamental relationship between these subjects and their application to everyday life. Hence they ask for the teaching of general science: by this they mean a systematic and organized course of study accompanied by adequate practical work and based on the elements of the physical and biological sciences, with special reference to their application in the life of to-day.

The British Association considered, in 1932, the report of a committee on general science in schools. This included a useful historical review which described the definite but relatively slight increase in the biological content of school science courses and the good pioneer work that was being done in the teaching of general science. The proper place of biology in school science was still undefined and some schools took it at an early stage, others late. Yet there was a general lack of public interest in biology and no clear agreement as to the scope and utility of biology in schools.

The views of this Committee were echoed in the Report of the Investigators of the School Certificate Examination

(1932). Their suggestion is that the teaching of general science might take up about one-eighth of the curriculum. The syllabus would require a knowledge of the work of the great experimental philosophers of the past, e.g. Newton, Priestley, Davy, Faraday, Darwin, and of their contribution to our store of knowledge. It might be expected that in this way children should understand the general methods by which knowledge has been won and the way in which it is applied in social affairs.

The suggestion of the investigators was that a qualifying paper on General Science should be set in the examination and that physics or chemistry or biology should be offered as well at the same standard as in previous years. The various examining boards are now considering whether they can introduce syllabuses in general science and one or two have already been provisionally adopted.

The place of general science in the schools has not yet been satisfactorily settled. Doubtless it is a good thing that the teaching of this subject has not yet passed the experimental stage. Within the last decade general science has come more into the limelight and in another five years some compromise may have been reached between the claims of its advocates and of those who stand for the subject sciences. Yet on broad educational grounds there is as strong a case here for the synthesis of subjects as there is in the case of history and geography courses.

Examinations

The importance of examinations has increased during the last thirty years with the growth of the secondary school system and the wide development of qualifications for entrance to the professions.

During the last decade there has been much critical discussion both of their reliability as a criterion of achievement and their effect on the curriculum of schools. This discussion has in the last five years come to a head on three points, first the value of the entrance test to secondary schools, secondly the function of the School Certificate Examination, and thirdly the technique of examining.

The entrance examination to secondary schools is important because it selects for higher education some 10 per cent of

the pupils of the elementary schools. C. W. Valentine published in 1932 an investigation into its reliability. He observed little correlation between performance at entry and order of merit at end of school career and he concluded that many pupils were admitted by this test to the exclusion of others of greater ability. Changes in order of merit usually occurred during the first year after entry, and thus he argued that the ordinary entrance test in English and arithmetic, with or without a general intelligence test, failed to test adequately the specific abilities such as those involved in secondary school subjects, e.g. languages, mathematics, and science.

The results of this investigation strengthen the growing conviction that better provision should be made for children whose abilities develop later than others. The present tests appear frequently to exclude pupils who may be specially gifted in music, arts, or crafts. On the other hand, a suitable group test, with interviews and reference to teachers' estimates of probable performance, minimizes these risks.*

The School Certificate examination for secondary schools is controlled by eight examining boards in England and Wales. Their standards have been co-ordinated since 1917 by the Secondary School Examinations Council, which issued in 1932 a report of an investigation of this examination. University requirements have come to have an excessive influence on the school curriculum owing to the fact that a pass in certain subjects can qualify for entrance to the University. The report recommended, *inter alia*, the dissociation of the School Certificate from Matriculation, and appropriate changes are now being made in the regulations of some examining boards. The abolition of honours and distinctions was recommended, as also the importance of the principle of easy papers and a high standard of marking.

Criticism of this examination ranges mainly around two points. It does not appear to be a fair test for pupils who have considerable practical or artistic abilities, but are weak in specific abilities. Again, failure to pass this examination is a severe handicap, and as the existing regulations debar some promising pupils, more elasticity in the group system is required.

* See W. A. Brockington, *A Secondary School Entrance Test*, 1934.

The technique of examinations has received considerable attention. An account of the machinery and results of School Certificate Examinations was given to the British Association by J. M. Crofts in 1927, describing careful measures which are taken to standardize marking and reduce discrepancies in border-line cases. Statistics correlated by D. Caradog Jones (1928) showed that in the School Certificate Examinations boys invariably excel in mathematics, chemistry and geography, while girls achieve better results in English, history, and languages. At the Higher Certificate stage the performance of the average girl is no longer equal to that of the average boy, and the superiority of boys in free competition for scholarships is strongly marked.

In 1935 a Committee of Inquiry reported on investigations into the marking of a secondary schools entrance test, an essay set for University entrance scholarships, School Certificate papers in history, Latin, French, and chemistry, and papers set at a University History Honours Examination. As might have been expected, considerable discrepancies were found in the marking of history and of English. The most useful experiment was a test of the reliability of interviews. Two boards of examiners interviewed sixteen candidates separately, and in their final placings, the candidate named first out of sixteen by one board, was placed thirteenth by the second board, while the first chosen by the second board was only eleventh with the first board.*

The Committee's report emphasized the need of careful marking in border-line cases and the necessity of replacing examiners whose judgment is faulty and who cannot observe consistency in marking. There was, however, a general feeling that it did not adequately recognize the value of the measures usually adopted to ensure a reasonable standardization of marking.

Reference to examinations inevitably brings in some consideration of the curriculum, but little space can be devoted here to experiments in the curricula of schools. Attempts have been made to synthesize the teaching of history, geography, and civics in the form of courses in social studies, as devised by F. C. Happold. A handbook published in 1935 by the Association for Education in Citizenship

* See *An Examination of Examinations*, by Hartog and Rhodes, 1935.

describes methods whereby citizenship may be taught through the various subjects taken in secondary schools. The value of arithmetic as commonly taught has come in for criticism. The movement to free the curriculum from being unduly influenced by examinations will, it is hoped, lead to further developments in these directions.

Physical Education

Physical education has assumed considerable importance in the last decade. The present generation lives more in the open air than its predecessors. The popularity of rambling (publicized as "hiking"), of sun-bathing, and swimming, and the organization of Youth Hostels may be said to date from 1928–30, and has been influenced by similar developments on the Continent, particularly the Youth Movement in Germany before the National Socialists assumed control. Hence the new interest in physical education has been wisely applied in the occupational centres for the unemployed, which in the last few years have developed physical recreation for interest and enjoyment.

In the schools the narrow formal and rigid type of drill has given place to a more elastic system that aims at developing not only sound physique but also self-reliance and intelligence. Moreover, the training has been adapted to the needs and capabilities of the various stages of childhood and adolescence and above all it has become freer and more enjoyable.

A comparison between the Board of Education's syllabus for 1919 and the revised syllabus of 1933 shows how considerable is the advance. There is now more individual work, the pupil co-operates more freely in the training, and the methods of teaching are more natural and interesting, proceeding from enjoyable games for the seven-year-olds through simple exercises to highly developed team work in which the teacher supervises instead of actively instructing. Rhythm and relaxation are notable features, while corrective exercises are co-ordinated with recreational activities in which the instinct to climb and jump is given full play.

Suitable free and light clothing is now invariably worn: fifteen years ago most boys and girls were over-clothed during exercise. Games are better organized and attention

is no longer exclusively devoted to members of the school teams. Swimming baths are now provided in most large modern schools: improved methods of filtration have stimulated the growing popularity of swimming.

Outside the schools the increased provision of playing fields on a national basis and the growth of the "keep-fit" movement among women are significant signs. This was appropriately signalized by the formation in 1935 of the Central Council for Recreative and Physical Training which co-ordinates and stimulates public interest in physical education.

Girls' schools have long been amply supplied with capable teachers from one or other of the several training colleges for women. Boys' schools, however, have for years suffered from a deficiency of competent teachers—in many boys' secondary schools physical education was in the hands of ex-army instructors with a limited outlook and not capable of teaching any academic subjects. In 1933 a physical training college for men was opened at Leeds with the aid of the Carnegie Trustees. This has now more than a hundred students: many of these are graduates, who will thus be able to teach academic subjects increasingly as they approach middle age. Moreover, most local authorities have now appointed organizers who supervise the physical training in the primary schools. The supply of teachers is thus assured in every direction.

Since 1928 the Board of Education have stimulated the provision of suitable gymnasia, first in secondary and latterly in central or senior schools. Most secondary schools have been supplied with a minimum of playing fields, but there is still urgent need for playing fields for primary schools.

In every direction physical education has made marked advances, and it has caught the public imagination more particularly since 1933. The boys and girls of this generation are physically fitter and more alert than those of fifteen to twenty years ago: if their minds are not sounder their bodies are at least healthier: there is developing at last a reasonable co-education of mind and body.

IX

ECONOMIC SCIENCE

By Sir Josiah Stamp, G.C.B., G.B.E., D.Sc., Sc.D., LL.D.

In the five years from the end of 1930 to 1935 a noticeable change—certainly greater than in any recent quinquennium—has come over many sections of economic analysis, due not so much to epoch-making developments in theory evolved in the study upon normal lines, as to the fact that "events are in the saddle" and have carried economists, whether they liked it or not, into territory much less known and understood in detail than they had imagined. The extraordinary world developments in various directions have stretched well-known economic principles either to the breaking point, or to a point where they seem to have been virtually reversed. For example, we have seen prices going so low that instead of supply shrinking to produce equilibrium, it has actually increased; we have seen money rates put down instead of up, to maintain supplies; we have seen budgets deliberately unbalanced to create confidence. In many ways the course of events has refused to answer to normal theoretical considerations, and economists have been busy elaborating particular branches of theory to deal with a set of abnormal circumstances, and to provide a background which shall be consistent both with the main body of teaching and with what has been happening. Industrial surveys and the field work at Liverpool, Manchester, Cardiff, Dundee, and elsewhere have improved the technique of applying academic work in economics to the immediate needs of the community and the statistical connections have been strengthened.

In the field of international monetary finance at the end of 1930, although the position was certainly out of equilibrium, it was hardly felt to be so at the time, and was still regarded as only an extension of disturbances explainable on normal lines. Britain had returned to the gold standard in 1925, and seemed to be successfully holding her position, but it proved to be only by methods which were unconsciously

sowing the seeds of future trouble. To prevent international balances moving away from London, New York, in loyalty to international ideals, had not long since made money in the States cheaper than was really good for the incipient Stock Exchange boom. The Macmillan Committee made an exhaustive inquiry into our financial position, and they recommended that additional information should be obtained to show the position of London as an international centre, particularly for short-term obligations. But even with the new information obtained, as it still omitted the position of the London branches of the foreign banks, they did not see the danger ahead. As the depression deepened and foreign distrust in the British political position asserted itself, the heavy drain upon London began. It was not corrected in the orthodox manner by raising the Bank Rate, for the trouble was too deep-seated, and that would have been so obviously a signal of distress as to have accentuated the trouble.

Now, for a period of five years, Britain has not yet returned to the gold standard, and the economic theory of banking and foreign trade in such conditions has been much more thoroughly worked upon than during the previous period up to 1925, when the sterling exchange had also been at large. Moreover, the long process of the depression has had profound effects upon the central monetary position of nearly all countries. The abortive international Financial Conference of 1933, when the monetary policy of the U.S.A. had to be entirely domestic in its outlook, and could not pay even lip service to internationalism, served to put the resumption of fixed exchanges into cold storage. Gold continues to be esteemed as the final source or store of value and, with the difficulty of making payments in exports, it has tended to concentrate in one or two centres, there to be neutralized, so that, both sought after, and then hoarded, it has appreciated to an abnormal extent. This again has deranged the exchanges throughout international trade, and the effect of these conditions upon economic theory has been to lead to a deeper exploration than before of the antithesis that was so clearly set forth more than twelve years ago by Mr. Keynes in his *Tract on Monetary Reform*. This was the incompatibility of an exchange system which endeavoured

to secure perpetual equilibrium or parity between the currencies of the world and, at the same time, allow each of the countries to maintain a level of domestic prices, or move it favourably to its own circumstances, its employment and development. It was clear that even with initial parities well established, if all the countries were not in the same position on the trade cycle, or if some developed more quickly than others, disharmony would be set up and the parities endangered. The question as to whether this double object can satisfactorily be attained and, if not, what degree of sacrifice should be made to either side's point of view, the domestic or the international, is still the subject of detailed discussion by economists. Practical bankers and politicians are opportunists awaiting a more stable condition of international and industrial affairs before attempting the re-establishment of any kind of fixed parities. On the whole, preoccupation with domestic recovery is still much greater than it is with the freedom of international trade, and monetary policy is being developed accordingly, with primary regard to domestic prosperity. New varieties of currency management are being explored. The American experiment, in buying silver to reinforce a credit base already oversupplied, meets with no support in economic circles; it is purely political. In Germany, the attempt to keep a façade of gold parity for the mark, while business of all kinds is done upon market values of different marks, is an eccentric novelty. French disinclination to face a second devaluation, only now overcome, gave an object lesson to economists in deflation. For the time-lag in recovery of those countries, which are attempting to do without the adjustments secured by devaluation of various types in others, is very conspicuous. The high hopes raised by a certain school of economists in America for the automatic raising of prices by Government action working on the financial machine, have been, to a large extent, falsified. Similarly, the British section of economists who would control the level of employment by operation upon the Bank Rate, *simpliciter*, have had serious challenge. It has been made clear throughout that when confidence is really destroyed the nicer adjustments of normal economic equilibria cease to have any virtue. No work on currency and prices in relation to economic

activity written prior to 1929 can be read to-day with any but historical interest. Monetary theory is now less of a special problem, and is rather more of an integral part of any theory of market movements.

The second direction in which events and theory have been developed together is in connexion with the basic causes of large scale unemployment and the difficulties of re-employment. Questions of dislocation of trade through fashion and transfer are certainly not new to economic theory, but the general question of unemployment as a chronic condition of the existing type of the economic machine is much more defined as a new problem. In the realm of theory Mr. Keynes's book on the Theory of Money at the beginning of this quinquennium has provoked discussions which are still reverberating. He brought into sharp relief new theories or versions of over-saving—the theory that saving and investment are not organically related, and upon their becoming widely different, owing to the completely different sets of forces and bodies which determine them, grave inequalities will ensue. The economic analysis, therefore, of saving and investment, and the little explored territory of theory lying between them, dealing with what actually happens in the way of deflation when they are unequal, has been one of the special features of this period. It is evoking the beginning of a theory of capital, whereas capital and its growth had been largely taken for granted. It has led directly into the field of government finance and State responsibility for unemployment or re-employment. If on the initiative of individuals, over-saving of the newly-defined type is prevalent, this disequilibrium brings about considerable reduction in employment, and the new analysis is designed to indicate that this may be balanced or corrected by collective investment on the part of the Government, not paid for out of taxation, which investment may restore the equilibrium because it is not made out of savings. It is aided by the fact that already in various kinds of unemployment relief, large sums are being spent "for nothing in return" and that it is only the difference between ordinary wages and such relief that is really in dispute as a burden. Hence the new discussion on the economic effects of unbalanced budgets is a direct consequence. The orthodox

doctrine, requiring all public expenditure to be met through taxation, is said to be merely transferring purchasing power from one spender to another, with no restorative effects. But the orthodox school hold that in this way only can the Government command confidence as sound financiers, and confidence is the basis of revival. The contrary view now being actively practised in the United States holds that an unbalanced budget coming to the aid of a domestic situation unbalanced in the opposite direction, is a necessary condition of revival of employment and that this action is more likely to command confidence than orthodoxy. A further matter arising thereout, and led by Messrs. Keynes and Kahn, is the question of the cumulative effects of such employment out of State expenditure. Every person so employed will spend his wages and employ others—what is the true "multiplier" and what are the conditions of its validity? Many of the ideas involved in this recent analysis are not so new germinally as the discussion of them in Britain. Thus it may be said that advance has been made in monetary theory, from several directions, developing the lines followed by Bohm Bawerk and his pupils for the last fifty years, and in this separate school we have moved also from monetary theory into the theory of output as a whole.

The mixture of economic mechanism and social and national psychology provides in full measure the basis for a very wide divergence in economic theory. The economics of under-consumption in all directions are being revived—the old Hobsonian theory with the new, and although Douglas credit theories even at the beginning of the quinquennium were widespread, they had not received the attention of academic economists to any extent, and were usually dismissed in a few words. They certainly made no headway with the Macmillan Committee. Now, however, those ideas are so prevalent, and are entering the field of practical politics in America and particularly in Alberta to such an extent that many able and considered economic analyses of the forces at work are being undertaken. Agitation is rife, especially, for example, in New Zealand. While no accredited body of economic teaching accepts these cruder forms of under-consumption—"poverty in the midst of plenty" and so on—the new analysis is undoubtedly exposing a

substratum of truth which lies behind the diagnosis of the social credit theorists, but which is not quite what they allege, and is not touched by their remedies.

Attempts at self-regulation of production in certain industries, to prevent excessive supplies at unremunerative prices, and further attempts at Government regulation with the same object, through the great disparity between potential production and the actual working of the economic machine under the conditions of a crisis of confidence, have brought "planning" to the forefront. In the five years there has developed a formidable attempt to sketch the lines of a planned economy on an economic basis. It is still urged by the sceptical, apart altogether from administrative difficulties and shortcomings of organization, that the elimination of the competitive and marginal price test must rob the economic organism of its main guiding control and principle. Analyses are now proceeding to show how far other criteria may be available and adequate for the purpose, e.g. statistical records of consumption and production, and various schedules of demand and supply, and alternative methods of testing at what points additional capital can be most profitably applied. This analysis is completely unresolved at present and no economics of a systematic economy are yet accepted. The recent emergence of the Russian experiment into a field of greater relative success and profitability is invigorating the theoretical discussion, and many of the most interesting contributions to economic literature relate to the extent to which the price mechanism can be dispensed with. The study of results in actual planning experiments in Britain, America, and Germany is having the effect of reinforcing that aspect of theory which teaches the interdependence of all values. Attempts to work upon particular values in isolation nearly always fail.

Those branches of monetary and industrial theory which link very closely the price of money or the bank rate and the quantity of money with the level of employment having received a severe setback, attempts are being made to deal with the problems piecemeal. It has been seen that whatever may be the case when a reasonable degree of confidence exists, and the parts of the economic mechanism are in fair interlocking balance, and however responsive total

production may be to monetary conditions in those circumstances, in times when a machine has broken down and when confidence is absent, manipulations of interest rates or even the quantity of money, have no immediate effect, and even their long period results are much less certain than had been thought.

The growth of economic nationalism—partly the fruit of the derangement of the exchanges and the semi-bankruptcy brought on by the inability of debtor countries to pay their debts with a reasonable export of goods—has brought about a new attitude of mind towards international trade. Not that the general theory of comparative costs has been touched, but realizing that the world has got to be dealt with as it is, an attempt is now being made, theoretically, to qualify *laissez faire* by more definite problems of national balance, and the attitude towards tariffs as a means to this end has undergone some change even in economic theory. The theory of international trade is developing again as a part of general theory, not as a special case, and domestic trade cannot be analysed without it. The purchasing power parity theory of the exchanges has come under scrutiny, and however fundamental it may be in the long run, it is seen to have very qualified action in the short period. The doctrines held steadily by economists as against politicians for fifteen years about the true nature of reparations and interallied debts, in their effect upon international trade, have at last been openly acknowledged to be accurate.

One of the most important modifications of the general background of economic thought is that brought about by population in its alteration of the tempo of economic change. The fact that the chief industrial nations have within early view the point at which their populations will reach their respective maxima, and then for some time will become stationary, and then decline, has introduced completely new features into the problem, and economic theory now has to take into account much more seriously the effects of economic maladjustments which were previously compensated by actual population changes and movements. The inability of the community to absorb economic maladjustments by the mere process of expansion, and the factor of stationary population on the more staple productions, are beginning to have

a profound influence upon economic thought, although it has not yet reached any popular expositions or political programmes. Prolonged unemployment and the political and humanitarian necessity for elaborate organization for its relief, are introducing features into economic analysis which, while no doubt present hitherto, were not emphasized to anything like the present extent. The drain upon public resources and the inability to take, even in a communal form, the products of the work of the unemployed as a partial set-off, have produced the worst economic dilemma in our time. Those who proceed on the old and orthodox lines, while allowing much for special reorganization of industry, believe steadfastly that confidence must be rebuilt, if not upon personal thrift, at any rate, upon Governmental thrift. The opposite school believe that such thrift has no saving virtue in it at all, but may make the situation worse. The search for an ideal balance between consumption expenditure and savings expenditure respectively is vital.

None of these problems is touched adequately by any of the literature of economic analysis in existence up to the year 1930. The books on monetary theory up to that point dealt predominantly with money as a measure of value and a means of exchange, and only cursorily with it as a store of value. It is this third function which has become predominant in the problem of uncertainty and the use of money as an insurance against change, and the theory of uncertainty and risk has run over from the theory of profit into the theory of money, which is becoming now the theory of the disposal of resources over or through periods of time. In the realm of pure theory Robinson's *Economics of Imperfect Competition* is perhaps a germinal contribution, and Professor Pigou's work on *Unemployment*, and *The Economics of Stationary States*, has yet to be absorbed in general teaching. The significance of imperfect competition is that, with all kinds of interferences with freedom of movement, due to Government interference, growth of monopoly, trade depression, restrictions, etc., the general theory of value has to be restated to cover the new conditions. When many points of the social mechanism are fixed, the behaviour of the rest must be different in meeting disturbances from what it would be if all the parts were freely working. Mr. Keynes

began the quinquennium with a great elaboration of an idea whose germ lay in a book published some years earlier by Mr. Dennis Robertson, *The Banking Policy and the Price Level*, but Mr. Keynes fitly finishes the quinquennium with a new work on the *General Theory of Employment and Interest*, which goes much farther in its alleged inroads upon classical economic analysis than any responsible book of this age, and its teachings are not yet absorbed nor widely accepted, but are the subject of highly specialist analysis. In the United States, the five years have produced in the main a "crisis" analysis, but largely through the impetus of the London School of Economics there is greatly increased interest in the work of Swedish and German economists and theory is becoming less national.

X

AGRICULTURAL SCIENCE

By Professor J. A. S. Watson, M.A.

In this article attention is confined to those scientific advances which, in the period under review, have begun to affect the practice of agriculture or which, at the time of writing, seem likely to find important applications. The range of subject-matter is naturally very wide, and it has been found necessary to exclude references to a good deal of work of potential importance.

Soils and Plant Nutrition

From one point of view the soil may be regarded as the source of plant nutrients, and its fertility as depending on the abundance or scarcity in it of a limited number of elements combined in forms which can be taken up by plant roots. It has long been known that three of these elements—nitrogen, phosphorous, and potassium—are of special importance to the farmer in the sense that a shortage of one or more of them often sets a limit to the yield of his crops.

In the early days of agricultural chemistry it was expected that a chemical analysis of the soil would disclose its requirements in the way of fertilizers, and thus provide guidance to the farmer. The difficulty has always been, however, to distinguish between those compounds of a given element that are actually available to the crop and those others, always much more abundant, that the plant is unable to absorb. Hence the farmer has had, in the main, to discover the fertilizer requirements of each crop, on his particular soil, by laborious trial-and-error experiments in the field.

In recent years two methods have been devised which attempt to find answers to the farmer's problems by means of relatively simple pot-culture experiments. Neubauer's method, which is already being widely used in advisory work in Germany, depends on the principle of using the plant itself to assist in the analysis of the soil. A sample of the soil is diluted with a fixed proportion of pure silica sand;

in a pot containing this mixture are sown a fixed number of carefully standardized seeds of rye. The pot is kept under controlled conditions of temperature, moisture, etc., for a period of seventeen days, when the seedlings are freed from soil and analysed. The uptake, e.g. of phosphate, by the seedlings is then taken as a measure of the supply of available phosphate in the soil and, from the figure so arrived at, the response of any particular crop to applications of phosphate can be predicted with some success.

The method of Mitcherlich is also one of pot culture, but the measure employed is the yield of the plant. The method depends on the assumption (not universally accepted) that if a plant be fully supplied with all but one of its essential nutrients then its yield-responses to successive increments of the remaining nutrient will fit a certain mathematical curve. If then, for example, we wish to determine the status of a particular soil with regard to the amount of potash which a particular plant can extract from it, all that is required is to conduct a trial with two pots. To the one is added a superabundant supply of every known nutrient; water supply, temperature, etc., are controlled at optimum levels, and the plant is thus enabled to produce its maximum growth. The other pot is treated in precisely the same manner, except that one particular nutrient—e.g. potash—is withheld. The reduction of yield, due to the withholding of the single nutrient, then becomes a quantitative measure of the deficiency of available potash in the soil, and the response of the crop in question to any particular application of potash can be predicted by reference to the curve.

In both cases further work requires to be done in correlating the predictions with the results of fertilizer trials in the field. Both methods, however, promise to be very useful.

Until a few years ago no particular importance was attached to the method by which fertilizers were applied to the soil, and the farmer commonly used the practically convenient method of broadcasting the material over the soil surface, and, in the case of annual crops, harrowing the surface so as to mix the material with the top layer of soil. This method, in fact, is entirely satisfactory so far as nitrogen is concerned, because nitrates penetrate the whole

depth of soil freely and rapidly. In the case of potash and phosphates, however, markedly different responses are sometimes obtained according to the region of the soil in which the fertilizer is placed. In certain types of soil the ordinary compounds of phosphorus are very firmly retained in the soil region where they happen to be placed, so that a surface application may fail to reach the zone of root action in time to be of use. The same is true, in a lesser degree, of potash, wherever the amount of colloidal material in the soil is high or the rainfall is low. In the case of annual crops much improved responses may often be obtained if the fertilizer be buried a small distance under the seed. A special difficulty arises in the case of fruit trees, where many years may be required for a fertilizer, applied on the surface, to penetrate to the depth where it will make contact with the tree roots. An interesting technique for quickly testing the nutrient requirements of orchard trees has been devised at the East Malling Station; a small boring is made through the stem of the tree and a dilute nutrient solution is siphoned directly into the wood. With the object of speeding up the action of a fertilizer, the method is being tried of dissolving the material in water and injecting it, by means of a pressure pump, directly into the lower regions of the soil. The results are promising.

An increasing number of cases are being found where the supplies of "minor" elements in the soil are inadequate to the full nutrition of the plant. Thus in Great Britain and Ireland quite important deficiency diseases of Sugar Beet (Crown Rot) and of Swedes ("Raan") are due to a shortage of available boron. Either trouble may be prevented, or even cured in its earlier stages, by applications of borax at the rate of ten or twenty pounds per acre. In other countries it has been shown that certain soils are deficient in sulphur, copper, and even zinc.

Agriculturists and especially horticulturists are watching with interest the current research work on plant hormones. The subject is discussed in the section on "Botany" in this volume. The likeliest practical application seems to be that of inducing the rooting of cuttings of those species which are specially difficult to propagate by this method; but it is also possible that the work will throw some light

on the obscure subject of the value, as manures, of animal excreta and plant residues.

Since the mechanism of base exchange and the function of lime in the soil came to be understood, the control of soil reaction by the farmer has been placed upon a much more scientific basis. It is now known that most individual species of plants flourish to the full only within a certain fairly definite range of soil reaction, and the critical acidity (the point on the *p*H scale where failure of the crop may be expected) has been determined for most of the important crop species. Thus a competent soil chemist is now in a position to advise a farmer whether a particular soil is too acid for the success of a particular crop and, if so, what quantity of lime must be applied to produce the desired result.

Much attention continues to be given to the classification and mapping of soil types and there is no doubt that, particularly in the newer countries, the work is providing real guidance in connexion with the whole problem of land utilization.

Progress has also to be recorded in the study of the moisture status of the soil, in the movement of soil water and in the mode of action of field drains.

It is now known that the so-called "capillary" movement of soil water has been greatly exaggerated and that the surface mulching of the soil is much less effective, in checking evaporation, than has been supposed. At Cambridge the mode of action of "mole" drains has been made clear, and at Rothamsted important progress has been made in studying the varying permeability of soils to water and the varying tenacity with which soils hold on to the water which they contain.

Crops and Plant Breeding

Current work in the improvement of wheat in this country is largely directed to the production of varieties with greater strength of straw. Of the various factors governing the growth of the wheat plant, an adequate supply of nitrogen compounds is perhaps the most important, and since synthetic nitrogen compounds are now very cheap the farmer would like to make much heavier applications of nitrogen

than he has been accustomed to use in the past. These heavier applications, however, involve the risk that the plants will be too luxuriant in growth to remain standing, and a lodged crop is not only troublesome and costly to harvest but fails to develop its grain normally. The difficulty is being met, in part, by applying part of the nitrogen late in the season—viz. in May. Such an application tends to increase the yield of corn without causing an over-luxuriant growth of stem and leaf; but even so the farmer must hold his hand for fear that a summer storm will lay his crop flat on the ground. Hence the importance of obtaining varieties with greater resistance to lodging. The necessary breeding work is being carried out at Cambridge as well as by various commercial seed firms.

The Oat problem is considerably more complicated. In the southern half of England spring-sown oats suffer severely and almost regularly from the attacks of frit-fly, and the varieties available for autumn sowing are either not fully winter-hardy or else are too weak of straw for modern requirements. At Cambridge, therefore, effort is being directed to the breeding of varieties which will combine winter-hardiness with stiffness of straw. One new sort is already available to the farmer. At Oxford promising results are being obtained in the breeding of spring sorts with a measure of natural resistance to frit-fly attack.

Fifteen years of brilliant work at the Welsh Plant Breeding Station has now made available to the farmer greatly improved strains of many of the species of pasture grasses. It has been shown that the old commercial strains (e.g. of ryegrass) are relatively stemmy and early flowering, with the tendency to throw a large part of their energy into seed production. They produce a relatively low proportion of leaf (which has a high nutritive value) and tend to have a low power of persistence under pasture conditions. The principles of improvement employed at Aberystwyth have been to collect indigenous plants from old-established grasslands; to select the most productive and otherwise desirable of these, and finally to build up relatively fixed strains. The work has been tedious for the reasons that the economic grasses are largely wind-fertilized, often self-sterile, and almost invariably subject to a serious loss of vigour when

they are brought towards a condition approaching genetic purity. Close "in-breeding" must therefore not be attempted, and completely homozygous or "pure line" varieties are out of the question. The strains that have been produced, however, are pure enough, in the genetic sense, for practical purposes, can be kept in this condition by continuous selection, and constitute an important advance on those that have formerly been available.

A bare reference must also be made to the most valuable achievement of the two British fruit research stations—East Malling and Long Ashton—in classifying fruit-tree root-stocks and in organizing the supply of standardized stocks to growers. The supply of classified root-stock material, produced by vegetative methods of propagation, is now adequate to the needs of the whole industry, and already the great majority of the trees supplied by nurserymen are produced by grafting on stocks of known behaviour, so that the vigour, time of bearing, etc., of the tree can be predicted with certainty.

The subject of polyploidy has been investigated in numbers of fruit trees and other economic plants, and a great deal that was formerly mysterious in their behaviour has been made clearly understandable. The subject is too large for an explanation to be attempted here, but the reader may be referred, for an illustration, to Hall and Crane, *The Apple* (1933).

The investigation of the relative values of different strains of the nodule-producing organisms of leguminous plants has been continued at Rothamsted. The inoculation of Lucerne seed with a pure culture of the Rothamsted strain is now standard practice, and is of real value in the successful establishment of the crop.* Interesting work is now in progress on the relative efficacy of the various strains of nodule organisms occurring in white clover. One at least of these strains is so unhelpful to the plant that the association may be described as one of parasitism rather than of symbiosis.

Various aspects of the complex subject of the ecology of pasture land have been investigated by Martin Jones and

* The botanical aspects of this practice are discussed in the earlier section on "Botany."

by G. H. Bates. The former has shown that the botanical composition of a pasture sward may be rapidly changed in any desired direction by controlling the intensity of grazing at the different seasons of the year. Thus, for example, if a sward contain given proportions of perennial ryegrass and wild white clover, hard grazing in winter and early spring will increase the proportion of clover at the expense of the grass, whereas winter and spring rest will make the ryegrass dominant. This is because the ryegrass tends to make winter growth while the clover remains dormant until late in the spring, so that the latter is unaffected at a time when the former may either be weakened or strengthened by variation in the treatment. Many other applications have been worked out in connection both with useful and with weed species.

Bates has shown that whereas certain species of pasture plants are severely damaged or even killed by treading, more especially if the surface soil be wet, other species suffer relatively little harm. The difference is connected with the habit of growth of the plant—whether erect or prostrate and whether its buds be above or below ground. It fortunately happens that the two most generally useful species (perennial ryegrass and white clover) are specially resistant to damage, so that many of the common undesirable plants may be expelled from the sward if the treatment be sufficiently severe. Bates has also devised an implement which stimulates the effect of treading and produces the same result.

The Cahn Hill experiments in the improvement of mountain grazings, which are being carried out by the Welsh Plant Breeding Station, are also full of interest. Their object is the replacement of inferior types of herbage, such as *Molinia*, *Nardus*, and Bracken, with valuable pasture plants like ryegrass, cocksfoot, and clover. The plan takes advantage of three separate steps of progress. On the one hand the track-laying tractor has provided a source of mechanical power for the cultivation of steep slopes and otherwise difficult land; again there are now cheap and abundant supplies of fertilizers, notably mineral phosphates and synthetic nitrogen compounds; and lastly many of the strains of indigenous grasses have been found to establish themselves, and to persist, under conditions where the common

commercial forms cannot maintain themselves in competition with the existing flora.

An interesting new economic plant is rice grass (*Spartina Townsendii*), to which reference has been made in the section on "Botany." This grass has been found to be very valuable in the reclamation of salt-water mud-flats and in the protection of sea walls. The work of Bryce is resulting in the widespread use of the plant along the Essex coast, and it is also being used in reclamation schemes in Holland and Germany. The plant dies out when the salinity of the soil has fallen to a certain point, so that it can be easily replaced by grazing species when it has done its particular task.

The researches on vernalization (see section on "Botany") are being watched with interest, particularly by horticulturists and glass-house growers.

Crop Pests, Diseases, and Weeds

A very important step in the control of seed-borne fungoid diseases (such as bunt of wheat and leaf-stripe of oats) has been the discovery of the value of certain organic compounds of mercury in destroying fungus spores without injury to seeds. These substances (e.g. tolyl and phenyl mercury acetates) may be applied to the seed as dry powders, which is a method very convenient in practice. They seem to be highly lethal to fungus spores in general, and to have no deleterious influence on the vitality of seeds. Their use has become general within two or three years of the demonstration of their value. A corresponding technique has been devised at the Jersey Agricultural Station, for killing the spores of potato blight (*Phythopthera*) which are often present on the tubers when these are dug. In this case the method is to dip the tubers in a dilute solution of formalin, though other materials are being investigated and may prove still more convenient to use.

The technique of spraying is making rapid progress. The value of tar oils as winter washes for fruit trees has been generally confirmed in practice and standard materials have been made available. The compounding of summer sprays to give simultaneous control of several distinct pests, both insect and fungoid, is another notable advance from the practical grower's point of view.

Various new materials have provided, or promise to provide, protection against insects that have been a source of severe damage in the past. Examples are the use of Pyrethrum against the Raspberry Beetle and of Derris, and naphthalene-silica dust, against the turnip flea-beetle.

The whole subject of the virus diseases of plants (see section on "Botany") has been under continuous investigation, and laboratory research is finding very important applications on the farm. In many of the vegetatively propagated species (potatoes, raspberries, etc.) the "degeneration" or "running out" of stocks has been a very serious and at the same time a very obscure problem. But since it was shown that this degeneration is due, at least in the main, to the accumulation of virus disease, the practical problem has been seen in its true light. The fundamental work on the potato, for instance, has been immediately applied by the Scottish Department of Agriculture, through a scheme for the inspection and certification of Scottish "seed" potatoes.

The control of weeds by chemical means is another sphere of work where rapid progress has to be recorded. Sulphuric acid spraying, introduced from France, has replaced the older copper sulphate spraying of weed-infested corn crops. Chlorates have been shown to be very useful general-purpose weed killers, though their cost is still too high for many purposes. Promising results are being obtained with ammonium thiocyanate, and other substances are under investigation.

Animal Nutrition

There has been a tendency among research workers in animal nutrition, for the past ten years or more, to change the direction of their investigations. The last generation of workers, including Kellner in Germany, Armsby in America, and T. B. Wood in England, concerned themselves mainly with the animal's energy and protein requirements, and with the energy values and protein-contents of particular foods. The present tendency is to concentrate upon what used to be considered the minor questions—of mineral requirements, vitamins, and the biological values of the different proteins.

This is not to say that our knowledge of the former aspects

of the subject is yet complete. It is still, in many cases, impossible to advise the farmer on the optimum level of nutrition for his stock—i.e. the level which will give the highest financial return. Some recent work on the pig has shown that the economic optimum food consumption may be considerably below what the animal could consume. On the other hand, artificial cramming of fattening fowls is generally profitable. Further work is required with other animals, especially in connexion with fattening.

It is true, however, that an inadequate supply of a particular mineral or vitamin is a frequent cause of definite disease and, what is perhaps more important, of an indefinite condition of more or less imperfect health. This latter condition may interfere with the animal's efficiency and may increase its susceptibility to parasitic or other forms of disease. It must also be remembered that modern intensive systems of animal production (like the "battery" brooding of chickens, indoor pig-rearing, and intensive winter milk production) remove the animal farther and farther from its natural environment, and, in the absence of full knowledge, make for increased risks of deficiency conditions.

As an example of the many successful investigations of mineral deficiency diseases, the recent work on nutritional anaemia in sucking pigs may be mentioned. This work has fully confirmed the original findings of McGowan at the Rowett Institute, Aberdeen—viz. that the condition is due to the inadequacy of the iron supply. The amount of this element in the milk of the sow is negligible—a fact that might be regarded as a curious lapse in Nature's provision did we not remember that the young of the wild pig, in its natural environment, is able to get abundant supplies of iron by rooting in the soil. But the domesticated pig has been selected for more rapid growth, and its iron requirements have therefore increased; so that if we shut up the animal in a concrete-floored sty, out of all contact with the soil, a more or less anaemic condition always develops up till the age when the animal begins to take food other than milk. Trouble may generally be prevented, however, by painting the sow's teats with a solution of an iron salt containing also a trace of copper.

Iron deficiency may also arise out-of-doors, but only on

peculiar types of soil. The once serious "bush-sickness," which occurs in certain parts of New Zealand, has been shown to be an iron deficiency condition, which is easily curable by the administration of iron salts.

Another example of the potential danger of the highly artificial environment is the occurrence of a paralytic condition in sty-fed pigs due (as has been shown independently by Dunlop and Golding) to a Vitamin A deficiency. This and many other similar diseases may, of course, be prevented by giving the animal a regular supply of fresh, green leafy material; or, failing this of artificially dried grass or lucerne; or, in the last resort, of a known source of the appropriate vitamin, such as cod liver oil.

The supply of Vitamin A to milch cows in winter has a special importance, inasmuch as the carotene content and Vitamin A potency of the milk depends upon the supply of carotene in the food. Many farmers now endeavour to maintain a supply of green food by growing winter-hardy plants such as kale, and it is one of the secondary advantages of the new process of grass drying (see below) that an easily stored carotene-rich food can be made available for the winter feeding of cows.

It has, of course, long been known that the proteins of an animal's food are broken down by the animal into their constituent amino-acids, and that these are reassembled in new proportions to build the particular proteins that the animal requires. It has been obvious, therefore, that the biological value of the food protein as a whole must vary according as the proportions of its various amino-acids approach near to, or depart far from, the proportions required by the animal. In the past, however, there has been no detailed knowledge of the amino-acids yielded by different proteins, and hence the practical feeder has gone on the principle of allowing a large margin of safety and hoping for the best. Thus, for example, there is no reason to believe that a milch cow is inherently inefficient as a converter of plant protein into casein and lactalbumen. Yet in practice it is found necessary to feed the cow about 0·6 lb. of protein in order to ensure that she will be able to produce, without drawing on her own protein reserves, the 0·35 lb. of protein contained in a gallon of milk. The large and important task

of measuring the biological values, for milk production, of the proteins of the common foodstuffs has now been undertaken at the Hannah Research Institute (Ayr) and elsewhere, so that it is reasonable to look forward to the accumulation of a body of knowledge that will make possible important economies in the feeding of milch cattle.

Animal Breeding

The genetical constitution of the higher animals is highly complex, and economic characteristics like milk production, egg production, and capacity to fatten are largely influenced by environmental conditions. Moreover Mendelian research involves the breeding of very large numbers of individuals, and the larger economic animals breed but slowly and are costly to maintain. It follows that many years must yet elapse before anything like a complete Mendelian analysis of the heredity of any farm animal will be achieved. So far it is only in the case of poultry, which can be bred under experimental conditions in reasonably large numbers, that genetical science is finding important economic applications. The best-known example of genetical synthesis is the "Cambar" breed of fowls produced at Cambridge, which is now nearly ready to be placed in the hands of commercial breeders. In this breed sex-linked colour factors have been combined in such a way that the sexes, within the pure breed, can be distinguished in the newly hatched chick. Formerly it has been necessary to cross two distinct breeds in order to obtain a batch of chicks in which the sexes could be distinguished.

As regards the larger animals a good deal of progress has been made by the application of statistical methods for the interpretation of milk records, in such a way as to make due allowance for the many environmental factors that affect the actual yield of a cow. The breeder has thus been enabled to form a much more exact judgment regarding the inborn milking abilities of his cattle. Progeny recording, as a means of measuring the capacity of a male to transmit milking propensities to his female offspring, is making fairly satisfactory progress. Hammond's studies of the physiology of reproduction have thrown light on many of the practical breeder's problems, such as the causes and cure of sterility.

The process of applying a progeny test to a breeding sire

is tedious and costly, and it is obviously an important matter that a male which has been so tested, and has been proved to be a valuable sire, should beget the maximum number of progeny. It has long been realized that a successful technique for artificial insemination would enable a vastly increased number of progeny to be bred from a particular sire, and thus multiply his influence upon his breed many times over. The technique for obtaining the spermatic fluid, for diluting it and for preserving its viability, has received a great deal of attention both in Russia and in this country, especially from Hammond and his co-workers at Cambridge. As an example of the measure of success that has been achieved may be quoted the case of an animal begotten by a sire on the Cambridge University Farm, and born to a dam in Poland.

Animal Diseases

Until very recent times the provision for veterinary research in this as well as in many other countries was extremely inadequate. The brilliant achievements of Sir Arnold Theiler and his fellow workers in South Africa first pointed to the vast possibilities of economic gain by the control of animal disease, and, since these were generally realized, the subject has received something like the amount of attention which it deserved. The new veterinary researcher has found a good many weapons, devised by workers in human medicine, almost ready to his hands; these have been used with great effect, and progress has been extraordinarily rapid. Perhaps the most notable of the earlier discoveries was that of Montgomerie on the value of carbon tetrachloride in cases of liver-fluke infestation of the sheep. The disease is one that has caused incalculable losses to sheep farmers in the past, and the treatment has been found to be cheap, easy and highly efficacious. The long-mysterious condition which the farmer described by saying that a farm or a field was "sheep-sick" has been shown to be due to the infestation of the land with internal parasites of the sheep, mainly small stomach worms. In this case regular drenching (with copper sulphate, nicotine, etc.) has proved very successful. The comparatively new Scottish Animal Diseases Research Institute has achieved a notable success in

discovering the life history of the organism responsible for Louping Ill in sheep. The Ministry of Agriculture Laboratory at Weybridge has a whole list of successes to its credit. Dr. Minett of the Royal Veterinary College has made important progress in the study of mastitis in cows and Dr. McEwen has contributed valuable work on the important group of sheep diseases caused by anaerobic bacteria. This list is by no means complete. Indeed there are very few important stock diseases with regard to which substantial progress is not being made. "Grass disease" in horses is an exception, for despite most strenuous efforts the cause of the condition still remains obscure.

Mechanization

It has naturally happened that the newer countries like the United States and Australia, where land is cheap and labour dear, have led the world in the invention of labour-saving machinery for the farm. Most of the notable new machines, like the large track-laying tractor, the combined harvester and the large combined seed-and-manure drill, have been introduced into this country from overseas. The most noteworthy contribution of this country has been the development of new processes for the conservation of grass and other green forage crops.

Large parts of the British Isles are singularly well adapted, by reason of their summer climate, to pastoral farming, our only important disadvantages compared with countries like New Zealand and Argentina, being the shorter duration of our grazing season. In the past the British farmer has mainly relied, for the winter feeding of his stock, on hay, root crops, and imported feeding stuffs like maize and oil-seed residues. Hay-making, however, is a precarious and often a wasteful process, root growing involves a large amount of human labour, and the stock farmer's bill for purchased feeding stuffs is often a very heavy one. An efficient process for the conservation of grass must therefore be of great value to the industry.

The first condition for success is to cut the grass in the young state, before lignification has reduced its digestibility. The mechanical difficulty of collecting short grass has been surmounted by devising a field machine which is capable of

cutting the short material and of passing it direct into a suitable vehicle. The next problem is to find the cheapest and most efficient method of preservation. Simple ensilage, which depends merely on the exclusion of air, is unsatisfactory for material of high protein-content, since undesirable fermentations are difficult to prevent. The addition of acid, in order to "pickle" the material, is a method that has been developed in Finland; conservation is fairly complete, even as regards the unstable vitamins, but the process is rather laborious and costly. The addition of fermentable sugar, in the form of molasses, leads to the development of a desirable type of fermentation producing chiefly lactic acid as the end product, and this process of ensilage cannot yet be left out of consideration. At present, however, the general view is in favour of artificial drying by means of hot gases. A number of different drying plants have been invented and about thirty are working commercially during the present (1936) season. It has been shown that conservation by drying is almost perfect so long as certain easily observed precautions are taken in the control of temperatures. There is practically no loss of digestibility, practically no breakdown of protein and practically no diminution in the carotene-content or vitamin-potency of the material. The fuel cost is not so high as to be a serious obstacle to the economic success of the process. The only serious remaining obstacle, indeed, is the high capital cost of most of the available drying plants, but cheaper driers are already making their appearance.

Agricultural Economics

The past five years have, of course, seen widespread changes not only in the technique of food production but also in the organization of the marketing and the control of trade in agricultural commodities. There has been a vast output of literature in the form of reports by various commissions and committees, which, however, does not admit of brief review.

The Oxford Institute has published a valuable series of studies under the title of *Progress in English Farming Systems* descriptive of various successful departures from traditional forms of farm organization. From the same

source have come a number of very competent analyses of the factors affecting the prices of agricultural products.

The survey method of investigating farm management problems has been developed, notably at Cambridge, and the analysis of the material collected has provided some important information about the factors affecting the financial success of the farming business.

Many new branches of the industry, such as sugar beet growing, mechanized corn growing, and outdoor dairying, have been the subjects of economic investigations, and a number of very useful papers have been published by Wyllie, and by other advisory economists, on the costs of production of various commodities.

XI

PHYSIOLOGY

By L. E. Bayliss, Ph.D.

It is not possible, within the limits of space available, to give an adequate account of all the work that has been done in the many branches of physiology. We can consider only those branches in which definite advances appear to have been made, but it is not to be supposed that the work done in other branches has not been any less painstaking and laborious; it has not yet come to fruition.

A. The Initiation and Transmission of the Nerve Impulse

During the past five years, our knowledge of the properties of the nerve fibre has been extended not so much as a result of new conceptions as a result of refinements of technique and the elaboration of old conceptions. Two of the most valuable technical advances have been the development of amplifiers and oscillographs on the one hand, and the development of thermometric devices sufficiently delicate to measure the rate at which nerve fibres produce heat, on the other hand. The first now allows us to record, with great precision, the potential differences—often very small and varying rapidly—between any two points on a single nerve fibre; the second allows us to assess the rate at which a nerve fibre is dissipating energy at any moment. This gives an index of nervous activity apart from the "action potential" and the contraction of a muscle to which the nerve may be attached, which have, so far, been the only indices available.

The Excitation of Nerves by Electric Currents. Recent investigations on the electrical properties of nerves are consistent with the conception that the nerve fibre is essentially a core conductor surrounded by a dielectric and surrounded by another conductor, so that there is distributed capacity, as in a submarine cable. In its resting state, the core is charged negatively to the external medium. If the potential of the surface is lowered by the application of a

suitable electrode connected to a source of electromotive force, this polarization is reduced; if the reduction is adequate, the dielectric breaks down, and a nerve impulse is started. There is now a potential difference between the active region and the neighbouring regions—the *action potential*—*action currents* will flow and bring about depolarization a little farther along the nerve. In this way, the nerve impulse is handed on from point to point along the nerve.

The characteristics of the applied e.m.f. necessary to initiate a nerve impulse have been known for a long time, but our knowledge has recently been extended and clarified.

(*a*) There is a reciprocal relation between the magnitude of the e.m.f. and the time during which it has to act which, for short times, is such that the total quantity of electricity required to initiate an impulse is constant. For longer times, this relation does not hold, since there is always a lower limit to the applied e.m.f. below which no excitation can be obtained, however long it is applied. This relationship is an expression of the time taken in depolarizing the nerve, owing to its capacity; for long durations, the leakiness of the dielectric sets a lower limit to the effective e.m.f. The time constant of the excitation—the *chronaxie* of Lapicque and the *excitation time* of Keith Lucas—has been found to depend on the dimensions and distance apart of the electrodes, and the diameter of the nerve fibre. The rate at which the impulse travels down the nerve, and the size and duration of the action potential wave, also depend on the diameter of the fibre, in conformity with the properties of the nerve fibre indicated above. All nerve impulses, therefore, are not exactly alike, and the differences, particularly in their time relations, may play a part in deciding their course through the central nervous system.

(*b*) The rate of change of the applied e.m.f. must be greater than a certain value, otherwise no excitation will take place, however great the e.m.f. becomes, unless and until, of course, the nerve is damaged by the heat generated. This *accommodation* indicates that the dielectric breaks down less and less easily as the stimulating current is maintained. The time-constant of the process does not depend upon the capacity of the nerve fibre, but to a considerable extent upon

the calcium concentration of the fluid bathing the nerve. Additional calcium increases the rate of accommodation and makes excitation more difficult; the animal becomes very sluggish. Reduction of the calcium concentration reduces the rate of accommodation, eventually to zero, so that not only is the excitability very high, but spontaneous excitation and muscular twitchings may occur.

The Transmission of Nerve Impulses Across Synapses. That nerve impulses were conducted across the junctions from nerves to muscles, and from one nerve to another, by special "transmitters," was first indicated, in 1921, by the fact that the fluid issuing from a perfused frog's heart would slow the beat of a second heart only if and when the first heart was slowed by stimulation of the vagus nerve. Conversely, the second heart was made to beat more quickly if the beat of the first was quickened by stimulating the sympathetic accelerator nerve. The *vagus stuff* responsible for the cardiac slowing was soon shown to have all the properties of acetyl-choline, and it was natural to look for it at other terminations of the vagus nerve trunk. This investigation was greatly assisted by the discovery that acetyl-choline is destroyed in animal tissues and blood by an enzyme—choline esterase—which hydrolyses it to choline and acetic acid, which are relatively inactive; this enzyme is inhibited by the drug eserine, or physostigmine. By the action of eserine, therefore, acetyl-choline becomes relatively stable even in the presence of animal tissues, and all its actions are greatly enhanced. It has been found that all the nerve endings of the para-sympathetic system, and the pre-ganglionic endings of the sympathetic system (the first junctions outside the central nervous system) transmit impulses by means of acetyl-choline, and are hence termed *cholinergic*. The post-ganglionic endings of the sympathetic system, however, transmit by means of the *accelerator stuff*. This has many of the properties of the hormone adrenaline, so they are termed *adrenergic*, but it has not, so far, been possible to identify it with adrenaline. Indeed it has some properties which are definitely different, so it has been given the name *sympathin*.

It seems highly probable, also, that the transmission of the impulses at the motor nerve endings in voluntary muscle is

brought about by acetyl-choline. The beneficial effects of the drug prostigmine—related to eserine—on the human disease myasthenia gravis, may be an expression of this.

Quite recently, evidence has been brought forward that acetyl-choline is released in response to the presence of excess potassium ions at the nerve endings. Since the potential differences in the nerve fibre are brought about largely by the migration of potassium ions (these are the most common cations within the nerve fibre), it is possible that this may be the means whereby the nerve impulse brings about the release of the transmitter at the nerve endings.

B. The Metabolism of the Heart

While no very great advances have been made in our knowledge of the chemical reactions that take place when a skeletal muscle contracts, considerable advances have been made in our knowledge of cardiac muscle.

In the frog, it has been shown that lactic acid is produced in the absence of oxygen, as it is in skeletal muscle. If the production of lactic acid is stopped by poisoning the heart with iodoacetate, the strength of the beat and the amount of creatine phosphate (phosphagen) remain unaffected for long periods if oxygen is supplied. In the absence of oxygen, the beat rapidly fails, and the amount of phosphagen in the heart rapidly falls. Since contraction of a muscle appears always to be associated with a breakdown of phosphagen, it is supposed that in the heart, the phosphagen broken down during each systole is re-synthesized, with the aid of direct oxidative reactions, during each diastole.

In the mammalian heart, also, the production of lactic acid from glucose has been demonstrated in conditions of poor oxygen supply. In the presence of oxygen, however, lactic acid appears to be utilized in preference to glucose; indeed, the combustion of lactic acid is the chief source of energy which enables the heart to do work. The glycogen stores of the heart are not used until the total amount of glucose and lactic acid available is very small; it appears to be an emergency reserve. Taken all together, these observations indicate that the heart does not ordinarily work on an "accumulator" mechanism, as do skeletal muscles;

this, indeed, is to be expected, in view of its continuous activity, and the impossibility of allowing it any rest. In other respects, its metabolism appears to be very similar to that of skeletal muscles.

C. The Carriage of Carbon Dioxide in the Blood

Until 1928, it was thought that this problem was settled. Briefly, the carbon dioxide produced in the tissues was supposed to combine with water to form carbonic acid. This acid ionized into bicarbonate ions and hydrogen ions, and the latter combined with haemoglobin ions to form an undissociated haemoglobin acid. This removal of the hydrogen ions is facilitated by the fact that reduced haemoglobin, which is a weaker acid than oxyhaemoglobin, is formed at the same time as is the carbon dioxide, as a result of removal of oxygen by the tissues. In this way the extra carbon dioxide formed is carried from the tissues to the lungs without any considerable change in hydrogen ion concentration.

It was pointed out, however, that the reaction $CO_2 + H_2O = H_2CO_3$ proceeds slowly in both directions, and that there is not time enough for it to be completed, even approximately, in either the tissues or the lungs. Either, therefore, carbon dioxide must be carried in some form other than bicarbonate, or there must be a catalyst capable of accelerating the reaction of carbon dioxide and water. In fact, both of these hypotheses have been found to be correct. The catalyst, carbonic anhydrase, is present in the red blood corpuscles only, and can be extracted from them in so active a form that in a dilution of one part in 7 millions, it doubles the rate of dehydration of carbonic acid.

It has been shown, also, that carbon dioxide is capable of combining directly with haemoglobin, largely in the form of a carbamino compound with the protein part of the molecule. While the absolute amount of this *carbhaemoglobin* present in the blood at any moment is not very great, it depends very largely on the amount of oxygen present simultaneously, so that the difference between the carbhaemoglobin content of venous and arterial blood is very significant. It has, in fact, been calculated that about 30 per cent of the extra carbon dioxide carried from the tissues to the lungs by a given quantity of blood is in the form of

carbhaemoglobin. It must be remembered, however, that the carbamino compound is itself an acid, and the reactions described above for dealing with the acidity of carbonic acid come into play equally for dealing with that of the carbamino compound.

The essential features of the pre-1928 conceptions, then, are not altered. They are no longer inadequate owing to the slowness of the reactions, since an enzyme is present to accelerate them, Quantitatively, however, some adjustments must be made as a result of the discovery of carbhaemoglobin.

D. The Secretion of Urine

It is generally agreed that, in essence, the secretion of urine takes place in two stages, (1) the formation of a protein-free fluid in the glomeruli, which is (2) modified in volume and composition as it passes down the tubules; this modification may result from the removal or addition of water, solutes, or both.

(1) *The Function of the Glomeruli.* That the function of the glomeruli in the frog is to filter off a fluid containing all the constituents of the blood plasma except the proteins was already fairly certain before 1930. In the last few years no less than ten different types of analysis have been made on the glomerular fluid, all of which are consistent with the conception of its being an ultra-filtrate of blood.

In the mammalian kidney, evidence has been collected recently, which, although circumstantial, is all such as to be most easily accounted for on the filtration hypothesis. For example, proteins are excreted by the kidney only if their molecular weight is less than about 70 000—a fact which suggests that the size of the molecule is the limiting factor in their passage through the glomerular membrane. Again, inhibition of tubular activity by cyanide or cooling results in the composition of the urine approximating to that of an ultra-filtrate of blood. Indirect measurements of the hydrostatic pressure in the glomerular capillaries indicate that the pressure available is more than adequate to allow filtration to take place; as soon as it falls below the expected limiting value, the secretion of urine ceases. Unfortunately, the internal arrangement of the mammalian kidney

precludes direct estimation of the composition of the glomerular fluid.

(2) *The Function of the Tubules.* Knowledge of the composition of the glomerular fluid forces us to postulate re-absorption of chlorides, glucose, and water in the tubules. Do the tubule cells secrete substances from the blood into the lumen of the tubules in addition to re-absorbing substances from the lumen into the blood? Recent analyses of the composition of the fluid in various parts of the tubules in frogs seem to indicate that certain dyes and urea are so secreted; other substances are excreted solely through the glomeruli, and subsequently concentrated, if necessary, by re-absorption of water in the tubules.

In the mammalian kidney, the observation that there is an upper limit to the amount of concentration that takes place in any given circumstances, and that this limit is the same for substances of very different chemical composition and physiological significance, such as creatinine, inulin and glucose (after phlorizin poisoning) suggests that the concentration is performed by means of the re-absorption of water. Certain dyes, however, which are strongly adsorbed to the plasma proteins, appear to be concentrated more than can be accounted for by the re-absorption of water only; they must be supposed to be secreted by the tubule cells.

E. The Sex Hormones

One of the remarkable developments in the physiology of reproduction in recent years has been the isolation and chemical identification of a number of substances capable of bringing about the changes in the accessory organs of reproduction that are normally brought about by changes in the gonads themselves. More remarkable still is their very close resemblance to each other and to cholesterol, and thereby to vitamin D, since all are built up on a cyclopenteno-phenanthrene nucleus. In all, so far, nine have been identified, falling into three groups with different physiological functions. The five substances in the first group, typified by *oestrone*, bring about the changes in the female accessory organs which occur ordinarily during the period of oestrus, or heat; three of these, *oestrone*, *oestriol*, and *oestradiol*, have been extracted from the ovaries; all five occur in the urine

of pregnant animals, the other two being given the names *equiline* and *equilenine*, since the urine of mares is the most potent source. Many other phenanthrene derivatives, also, have oestrogenic activity.

Progesterone, typical of the second group, has the effect of initiating and maintaining the condition of pregnancy when given during oestrus—natural or artificial—with corresponding actions on the accessory organs. Progesterone is found in the corpora lutea of the ovaries, and *pregnandiol*, the other member of the group, in human pregnancy urine.

In the third group are the two male hormones *testosterone*, found in the testes, and *androsterone*, found in urine, both male and female; both of these have the same action in maintaining the activity of the male accessory organs of reproduction.

The Anterior Pituitary Body and Reproduction. The control exerted by the gonads on the accessory organs by means of the hormones just considered is not automatic, but depends on stimulation by the anterior pituitary body. Removal of the pituitary in immature animals prevents sexual development; removal in mature animals stops the activity of the reproductive organs. The anterior pituitary body is responsible for the production, therefore, of the gonadotropic hormones. Their action is to produce (1) maturation of the Graafian follicles in the ovaries, (2) secretion of oestrin, which brings about the changes in the accessory organs, (3) ovulation (discharge of ova from the ripe Graafian follicles), and (4) the formation of corpora lutea from these follicles. There is evidence for the existence of two gonadotropic hormones: (*a*) follicle stimulating (F.S.H.) and (*b*) luteinizing (L.H.). F.S.H. increases the number and size of the Graafian follicles. L.H. converts mature follicles, which have been produced spontaneously or by the action of F.S.H., into corpora lutea. F.S.H. also stimulates spermatogenesis in the male, while L.H. produces hypertrophy of the interstitial tissue of the testes. Probably, therefore, the same substance is produced by the anterior pituitary body in both males and females. Taking this in conjunction with the close chemical similarity between the male and female sex hormones, just indicated, sex differentiation would seem to be due more to differences in the structure of the cells than to differences in the hormones

F.S.H. is found in the urine of women who have no functional ovaries, i.e. after their removal, or after the menopause. L.H. is found in the urine of women during pregnancy and its presence forms the basis of the recently introduced tests for early pregnancy. Both are found in large quantities in the placenta.

The anterior pituitary body also secretes a lactogenic hormone, *prolactin*. This produces lactation, even in males, after previous treatment with oestrin. Progesterone, also, increases the development of the mammary glands, but prolactin appears to be necessary for the actual production of milk.

There appears to be a reciprocal action between the anterior pituitary body and the gonads, since both oestrin and the male hormones depress the activity of the pituitary. The activity of the gonads is thus self-regulatory, since the stimulating action of the pituitary is damped down as soon as their activity becomes excessive. Such regulatory action might easily lead to rhythmic activity, and may play a part in producing the rhythmic activity of the female reproductive organs.

XII

BIOCHEMISTRY*

By Professor Sir Frederick Gowland Hopkins, O.M., D.Sc., Sc.D., LL.D., F.R.S.

PROGRESS in biochemistry during the period under review has been rapid in all its branches. During recent years the number of workers engaged upon its problems has steadily and rapidly increased, and the output of research during each quinquennial period has become very great. Annual reports dealing with its literature and covering the last four years of the five to be reviewed, contain references to some 9 000 papers, while most contributors to these reports have nevertheless had to admit the necessity of dealing selectively with the available literature.

It is clear that any brief summary of such progress must be presented in very general terms, and the nature of the main advances must be indicated by a few chosen cases out of a multitude.

Activities in the application of chemistry to living systems divide naturally into two main categories. The first comprises the separation of pure substances from these systems, and the determination of their molecular constitution and physical properties. This category presents, of course, opportunities for the organic and physical chemist, and of late many among the most highly qualified of these have come to the aid of biochemistry. Activities of a different kind deal with the functions and fate of these constituent substances during the active processes of life. They call for different technique, and at present are the task of the biochemist as a specialist.

Prominent quantitatively in every living system are, of course, the proteins. Much work on these complex compounds was done during the period under review, and, largely as the result of the application of physical methods

* This section and that on "Zoology" necessarily touch upon certain subjects, common to both, which it would have been inappropriate to exclude from either one or the other.

to their study, knowledge concerning them advanced on new lines. Based essentially on principles which allow conclusions to be drawn from the rate at which proteins separate from their dispersed condition in aqueous media when centrifuged at high velocity, a method for determining their molecular weight has been profitably applied. In the case of several this proves to be of the order of 3 500, and in the case of others multiples of this weight. Other investigations into the physical properties of various proteins when in solution have been numerous and informative. X-ray studies of the specialized proteins of silk, hair, and wool have demonstrated important characteristics of the polypeptide chains of linked amino acids contained in them, and such studies are throwing light on the molecular pattern of other more typical proteins. Meanwhile the study of individual aminoacids has progressed, and elegant new methods for the synthesis of polypeptides from these have been established.

Gaps in detailed knowledge have been filled up concerning the constitution of innumerable other important constituents of living cells and tissues, and there are relatively few among the known constituents of which the approximate, if not the exact, molecular structure remains now uncertain.

Such increase in knowledge concerning the pure chemistry of substances of biological importance greatly helps every effort to understand the nature and course of the chemical events in living systems, and it is characteristic of recent advances in biochemistry that substances previously supposed to have merely static functions as parts of cell-structure are being found to possess active functions in the dynamics of the cell, or to represent essential stages in the progress of reactions in the cell.

Notably, in illustration, is this true of the group of *sterols*, of which cholesterol as a structural constituent of the cell was the earliest known member. Some thirty years ago a close study of these substances began. It was early shown that the bile acids are closely related to the sterols, and much patient work was spent upon both. It became recognized that the central structure of their molecules comprised three six-carbon rings in association with one five-carbon ring, and much was established concerning the particular additions

to this common structure which are special to each individual member of the group. Up to 1932, however, a wrong assumption had been made concerning the relation between the central rings, and this led to many difficulties in interpretation. In the above year, however, an acute reconsideration of the meaning of an observation made five years before completely cleared up these difficulties. It is now known that the fundamental structure of the sterols contains the three-ring structure of phenanthrene associated with the fourth five-membered ring in clearly established relations. This advance stimulated ideas and work in various fields of biochemistry, and we now know that an apparently unconnected series of physiologically active substances, a crystalline vitamin, the oestrogenic and other sex hormones, carcinogenic hydrocarbons, and alkaloids acting on the heart, all have a phenanthrene nucleus in common. Such advances were characteristic of the five year period. A further illustration is found in the rapid growth of knowledge concerning the nature of vitamins, which occurred during these years, a field in which constitutional studies were long delayed because of the minute amounts in which these active substances are produced at their seats of origin. Of the six or seven vitamins known with certainty to exist, each exerting its specific influence on the animal body, the molecular structure of two (Vitamins A and C) is accurately known and commercial synthesis is in one case based on this knowledge. Another, that already mentioned as a sterol derivative (Vitamin D), can be made artificially, and of a fourth (B_1) the constitution is at least approximately known. Knowledge of others grew rapidly during the five years, and final constitutional knowledge is near at hand. It is interesting to find that fundamental differences in molecular structure are associated in vitamins, as in hormones, with the wide differences displayed in their functions. It is a future task of biochemistry to discover, here as elsewhere, the correlation between structure and function, and to explain why a molecule possessed of this or that particular configuration should, rather than any other molecule, influence a particular series of chemical events in living tissues.

Brief attention must now be given to certain of the more important and characteristic advances in our knowledge of

these multifarious chemical events. The increasing knowledge of their nature and course is, as might be expected, largely due to increasing efficiency in technique; in particular in the ability to maintain normal survival processes in individual tissues when they are removed from the body to be studied *in vitro*, and in the remarkable accuracy now attained in the use of micro-methods of analysis.

An outstanding illustration of the kind of progress reached by the use of such technique was offered by the demonstration in 1932 of the stages by which urea is formed as the end product of protein metabolism. Since the liver can form urea by the direct removal of the elements of water from ammonium carbonate, it had long been thought that this was the ultimate event in the process. The facts are not so simple. The ammonia and carbon dioxide produced in metabolism are, it is true, the precursors of urea, but the chemical mechanisms which determine its formation are complex. At the centre of events stands the molecule of ornithin ($\alpha\delta$-diamino valeric acid), the concentration of which remains constant throughout the process. It acts in this sense as a catalyst. A molecule of ammonia and one of carbon dioxide unite with ornithin, a molecule of water being eliminated to form the substance citrullin. Each molecule of this then unites with another molecule of ammonia, again with elimination of water, to form arginine. Arginine once formed comes immediately under the influence of the specific enzyme arginase, which is always present in the liver. By this the arginine molecule is hydrolysed, urea is produced, and ornithin reformed. A cycle of change is thus established and continues. In the absence of ornithin, no urea is formed by the liver cells. Unexpected and apparently unnecessary complexity may thus be met in biochemical events, the explanation of which is probably to be found in the circumstance that these events, though they may proceed when isolated, occur in the cell amid a dynamic environment. They are involved in time relationships with other events, and often in supplying energy at the right time and in the right place. A shorter path to the end result might not permit of such adjusted relations.

We find another example of this complexity in the biochemistry of muscle. The energy of muscular contraction

is derived from the oxidation of carbohydrate, but the chemical events which ultimately render this energy available for the mechanical act of contraction are many, comprising the sequence in due order of a number of related reactions. Phosphoric acid plays a remarkable part in these. At definite stages in their sequence the phosphoryl group is transferred from one organic molecule to another, and one marked advance which occurred towards the end of the five-years period was the arrival of a better understanding as to how this material transfer couples the reactions, and allows of energy transfer from one to the other. Between 1930 and 1935 some 800 papers were published bearing upon the chemistry of muscle!

Such cases must serve as bare examples of an increasing ability to follow in detail the course of chemical reactions as they occur during life. The five years brought forth at the same time a substantial increase in our knowledge of the catalysts and catalytic systems which determine and control these reactions. Notable among aspects of advance in enzyme chemistry is the isolation of pepsin, trypsin, and urease in the form of crystalline proteins. The view has long been held that enzyme-structure involves a colloidal protein carrier with which is associated a specifically active prosthetic group. If, as seems now to be proved in the cases mentioned, a protein molecule can itself display specific enzymic activity, we have yet to learn what kind of modification in its polypeptid structure differentiates it in this respect from ordinary proteins. It is remarkable perhaps that a protein should hydrolyse proteins. With regard to this hydrolysis it is noteworthy that we have learnt during these last few years how, in the breakdown of the complex polypeptid structure of proteins, as in their physiological digestion for instance, a whole series of specific enzymes play their parts in sequence.

Increasing evidence goes to show that in living tissues catalytic systems, comprising an enzyme with other associated factors necessary for its activity, are common; in particular what are known as co-enzymes exist, usually being relatively simple molecules of which the nature and constitution are in some cases known. These especially characterize the catalytic mechanisms concerned with the

oxidations and reductions which provide energy for the activities of living organisms.

Certain of these last, the *dehydrogenases*, exert their influence by making mobile the hydrogen contained in organic molecules, while those of another type, the *oxidases*, are concerned with the activation of molecular oxygen. In addition, however, to the combined influence of dehydrogenase systems and oxidases the effective transference of hydrogen to oxygen commonly calls for the intervention of intermediary "carriers" of the former; substances which are themselves capable of reduction and oxidation. The alternation of these two processes leaves these intermediary agents themselves in unchanged concentration; their influence is therefore essentially catalytic. To these as well as to the other factors concerned in biological oxidations much attention has been given, and much real and enlightening knowledge has been won concerning them.

The progress so far illustrated has been chiefly from studies of fully developed tissues. Chemical embryology is, however, a growing branch of science, and much significant knowledge is accumulating concerning the chemical events which are associated with the development of the embryo. Outstanding is the realization that a definite chemical substance produced locally in the early embryo is responsible for evoking specific lines of development at subsequent stages. This substance, though its formation in the embryo is strictly local, is widespread in adult tissues, and its general nature is approximately known.

The studies which up to now have received reference have dealt more particularly with the biochemistry of the vertebrates. The chemical potentialities of living systems cannot, however, be properly explored, nor what is basically essential, in the chemical sense, to the display of life itself be rightly appraised, unless the biochemist extends his activities over the widest possible field.

Comparative studies have now become numerous, and their results very profitable; the resemblances and the differences displayed in different animal phyla are alike highly instructive to all who wish to reach just views concerning the fundamental nature of living matter. Such studies moreover are preparing the way for an understanding

of what may be termed the "chemistry of evolution"—the nature of the chemical differentiations which underlie differentiation in visible form and function.

In plant biochemistry important advances were made during the period under review. A few only can be mentioned in illustration. That the growth of plants, like that of animals, is stimulated and controlled by hormones, was established just before the period began. The five years, however, produced much fresh knowledge concerning the chemical nature of these growth promoting substances—*auxines* as they have been called.* That mineral nutrition of plants calls for several elements previously believed to be dispensable is a fact now well established. This is true of boron and manganese and probably, in many plants at any rate, of copper and aluminium. That the need for certain substances in very minute amounts is just as great as that for others in much larger amounts is true of the animal and plant alike. It is probably true of every living system.

Considerable advances have been made in the chemistry of chlorophyll,† and very fine researches have established the exact constitution of a great number of the anthocyanins, the most prominent of floral pigments. In relation with the latter, interesting studies are connecting colour inheritance and colour variations with the known genetic constitution of the species concerned.

Research dealing with the chemical activities of micro-organisms has contributed and continues to reveal a variety of striking facts which are influencing to an important degree the intellectual outlook in biochemistry. The chemistry of alcoholic fermentation has long been the subject of close study, and the work of recent years has provided us with a nearly complete picture of the complex stages in which carbohydrate is broken down by the organism; stages of which the first resemble, and then later depart from, those displayed in vertebrate muscle. Both obtain energy from carbohydrate, but the muscle does external work while the yeast cell has only to grow. The lessening of the rate of fermentative processes when that of respiration increases,

* See, further, the section on "Botany."

† Further reference to these will be found in the section on "Organic Chemistry."

a phenomenon to which Pasteur gave much attention, is probably a fundamental biological happening common in various degrees to all living systems. Much work has been done towards finding the chemical mechanism which secures this adjustment, not yet with complete success.

Intensive studies of the metabolism of bacteria have been numerous, dealing with them not as agents of disease but as a special type of living cell of which, as in the case of yeasts, the only self-related function is apparently that of rapid growth. Among unicellular organisms bacteria appear to be exceptional in the extent of their equipment with specific surface catalysts. The number and variety of the reactions they can induce in their growth medium is remarkable. The study of these reactions has progressed of late by so dealing with the organism as to prevent its growth while leaving many of its catalytic powers intact. Products which disappear in the synthesis involved in growth then remain in the medium for study. Of great biological interest is the knowledge recently won concerning the energy relations in bacterial growth, especially in the cases of the autotrophic bacteria which grow in inorganic materials alone, and of the anaerobic group which dispense with oxygen.

A very thorough investigation into the metabolism in moulds has revealed the remarkable power possessed by these organisms of synthesizing a great variety of substances, among them many aromatic compounds, from glucose supplied in their growth medium.

Many chapters in the history of progress have perforce gone without reference. In the domain of chemical pathology, for instance, particularly in the chemical side of immunology, and in the biochemistry of cancer, advances of importance have been made, and also in the application of biochemical methods to diagnosis.

In this brief review only illustrations of the nature of the advances made could be attempted. Biochemistry is a relatively new branch of science, but it is now advancing rapidly on many fronts.

XIII

PHYSICS*

By Professor Allan Ferguson, D.Sc.

It is the business of this section to give some account of recent advances in, and of the present state of, physical science. It is, however, quite impossible in an introductory survey to present any clear and convincing picture of physics as it stands to-day without a rather detailed consideration of the astonishing change which the discoveries of the last generation have wrought in our attitude towards the fundamentals of physics.

Nineteenth-century physics had its origins in the great synthesis made by Newton, who showed that it was possible in an ordered and relatively simple way, to build up a scheme which should account for the changes of position of bodies of such dimensions as directly to affect our perceptions. The motion of a pendulum, a billiard ball, a railway carriage, and (with certain reservations concerning fine points) the complex motions of the bodies of the solar system, may be accurately and compendiously described by means of a machinery which is based on Newton's Laws of Motion. True, there are serious logical difficulties in the formulation of these laws. *Mass* is not an easy concept, and it does not simplify matters if, following classic authority, we define mass as the product of density and volume, having no other means of defining density than as the ratio of mass to volume. One of the most important and difficult of the tasks that faced the nineteenth-century physicist was that of clarifying the concept of mass—a feat accomplished by the construction, *in thought*, of a model universe which, in its simplest form, may be conceived as consisting of two particles (and a frame of reference). We visualize these

* In this section I have drawn on the substance of the Presidential Address to Section A at the Blackpool (1936) Meeting of the British Association for the Advancement of Science. The reader is referred to that address for a discussion of certain topics omitted in this section. The subject of Relativity is not touched on here. Some aspects of this topic are dealt with in the section on "Astronomy."

particles as moving in such a manner that, however their *velocities* may alter, the rates at which their velocities change (their *acceleration* in a word) preserve an invariable ratio to each other. And the ratio (acceleration of A)/(acceleration of B) is *defined* as equal to the ratio (mass of B)/(mass of A).

A model universe built up of a vast number of such particles may be constructed which will imitate, to a very high degree of accuracy, the facts of perception.

It must not, however, be assumed that this synthesis, satisfactory though it proved to be in many ways, was commonly used by nineteenth-century physicists. Quite otherwise; mass was customarily defined as *quantity of matter*, and matter itself as "that which can be acted upon by, or can exert force," or even more obscurely as "that which may have energy communicated to it from other matter." The physicist of that period was, indeed, apt to direct one's attention (and small blame to him) to the glories of the building rather than to the strength of its foundations.

Early in the nineteenth century discoveries, mainly in the realm of chemistry, gave fresh interest to atomic doctrines, and the concept of what we may term the "perfectly elastic billiard ball" atom proved to be brilliantly successful in explaining old happenings and in predicting new ones. It is by no means obvious that the extrapolation, to conceptual particles of infinitesimal dimensions, of laws governing the movements of bodies of macroscopic size is likely to supply a model which will serve to subsume certain perceptual happenings; the marvel is, not that such an astonishing extrapolation should break down at some point, but that it should have any validity at all. And the successes with which the hypothesis must be credited are sufficiently remarkable. Consider, for example, the explanation given by the theory of the curious observation that, whereas the viscosity (or stickiness) of a liquid decreases rapidly as its temperature rises, the viscosity of a gas *increases* with increase of temperature. Expressions for the magnitude of the viscosity of a gas may be arrived at in terms of a method which is most easily illustrated by the well-known analogy of two railway trains proceeding side by side at steady speeds in the same direction along parallel lines of railway, one train having a speed slightly greater than that of the other.

Imagine now that the passengers (all of equal mass) indulge in the reprehensible practice of leaping from one train to the other, as many passengers leaving train A in a given time as leave train B. Every passenger, in virtue of the motion of his train, possesses momentum (mass × velocity) parallel to the rails, and a passenger who leaps from one train to the other *carries this momentum with him.* The slower-moving train, therefore, *gains* momentum parallel to the rails from the exchange of passengers and the faster-moving train *loses* momentum by the exchange. The net result of the process is to tend to equalize the speeds of the trains.

So with two streams of gas in motion as a whole relative to each other. The particles in the layers, besides their general stream-motion, are in lively random movement (their mean random velocity, V, is of the order of that of a rifle bullet), and in their passage from one stream to the other, carrying with them their stream-momentum, they tend to wipe out the relative motion of the two streams. Which is precisely the effect we expect from the viscosity of a fluid. A very simple calculation shows that the viscosity of a gas is proportional to the velocity V of its molecules, and since this velocity increases with the temperature, so does the viscosity.

It would be an over-long task even to catalogue the successes of the atomic theory in its simpler form, and we must pass on to a brief consideration of another of the great theories of the pre-quantum days—the theory of radiation and of the mechanism by which radiation is conveyed. Despite the difficulties encountered in framing a dynamical theory of the ether, the concept proved to be so fruitful in elucidating the most diverse phenomena as to draw from Lord Kelvin the downright statement, "This thing we call the luminiferous ether . . . is the only substance we are confident of in dynamics. One thing we are sure of, and that is the reality and substantiality of the luminiferous ether." There are no doubts or hesitations here; and such expressions of certainty are pardonable—we hear them to-day concerning other physical theories—when we remember that, as early as 1833, the wave theory was competent not only to explain the ordinary phenomena o

interference and diffraction, but to predict the hitherto unsuspected fact that a light-ray, incident in a certain direction on a plate of the crystal arragonite cut in a specified manner, would be refracted as a *cone* of rays.

There is to-day a certain amount of rather loose talk prevalent concerning nineteenth-century and Victorian materialism. True, there was Buchner; and there was Tyndall's Belfast address to the British Association. But *Dr. Stoffkraft* had rather a restricted following, and much of the so-called materialism of the age was no more than the simple realism which many of us affect to-day when we put the reality of an atom on the same basis as the reality of the table at which we write without inquiring too closely into the meaning of the term *reality*.

Nineteenth-century philosophy, in some of its aspects, recognized clearly enough that the concept of the atom was simply another part of the physicist's mental shorthand; the atom might or might not—and these words are to be taken at no more than their face value—swim into the region of direct perception. Were it to do so, there is little doubt but that a new conceptual shorthand would be introduced to correlate these additional facts of perception. But so long as the atom remained a concept, there was, and is, a school of thought which insisted that talk of its reality was beside the mark.

Molar mechanics, the atom, the ether—the nineteenth century had reared on these apparently stable foundations an immense and imposing structure of ordered knowledge; with the closing years of the century there came the realization of the existence of cracks in the structure and weaknesses in the foundations. The facts of radio-activity and the discovery of the electron showed that the concept of the atom must increase in complexity if it were to continue competent to cover these additional perceptual facts. And the experimental study of the radiation from a hot body revealed a state of affairs inexplicable on the lines of classical theory. A hot body radiates energy to its surroundings; and if the radiations are passed through a prism they may be drawn out into a spectrum. How is the energy of the radiation distributed between the different wave-lengths? The answer to this question may be obtained without serious

difficulty, and the undisputed fact is, that if we plot a curve, the points on which show values of the energy associated with a certain wave-length plotted vertically, and the corresponding wave-length plotted horizontally, we obtain a curve having a cocked-hat shape, a definite maximum of energy being associated with a certain wave-length—this, for a temperature of the radiating body of, say, 1 000° C. Now repeat the experiment with the hot body at a temperature of 1 500° C. A similar curve will be obtained, with the peak of the hat (the maximum) shifted into the region of *shorter* wave-length. What have nineteenth-century theories of the ether to say to this? Their answer is clear, and gives a curve which coincides with the cocked-hat curve in the region of long wave-lengths, but exhibits no maximum and goes hopelessly away from the experimental curve as the wave-length decreases. Classical physics can give no other answer—and the answer is wrong.

Planck, in the last year of the nineteenth century, supplied a solution giving a curve which very closely fits the cocked-hat curve—a solution which has revolutionized physical thought, and has incidentally provided the language with a new verb "to quantize."

What do we mean when we speak of *quantizing* energy?

To quantize a physical quantity is to restrict its magnitude to a number of discrete, separated values which are integral multiples of a certain selected unit.

Planck, then, assumed that a hot body consisted of a number of oscillators which, in their simplest form, may be conceived as massive particles oscillating along straight lines in simple harmonic fashion with definite frequencies. The energy of such an oscillator is easily enough calculated and Planck's drastic assumption is that the possible values of the energies of the oscillator are to be restricted to a series of integral multiples of a unit which is itself proportional to the frequency. The unit may therefore be written hn where n is the frequency and h is a constant of proportionality which is called *Planck's constant*. And energy is emitted in integral bundles or quanta, measured in terms of this indivisible unit hn. As the energy itself is expressed in terms of the amplitude, this leads at once to the fact that a set of discrete separated values of the amplitude is possible.

Viewed in the light of the older physics, the assumption seems violent but it provides a radiation formula which fits the experimental curve.

Turn now to another experiment which is quite inexplicable on wave-theory lines. An insulated negatively-charged metal plate (zinc, for example) when exposed to ultra-violet light loses its charge—loses electrons, that is, in terms of our picture. Certain facts emerge from a close study of the experimental conditions. If, for example, the frequency of the light is below a certain threshold value, then, however great the intensity of the light may be and whatever the length of time of exposure, the zinc plate keeps its charge. If, however, the frequency is raised above this threshold value, the charge begins to leak away at once, and this, though the intensity of the incident light be so small that, on the basis of the wave theory, it would take days to accumulate sufficient energy to release an electron with the kinetic energy which it is observed to possess. Moreover the rate of emission increases in exact proportionality with the increase in the intensity of illumination.

If we take the view that light consists of *photons* (bundles or quanta of energy, each of magnitude hn, travelling with the velocity of light), then if a surface atom is struck by a photon it absorbs the energy of the photon and emits an electron which has to do work in freeing itself from the surface, and we may equate the sum of this work and the kinetic energy with which the electron leaves to the energy possessed by the original photon. A little consideration will show that this explanation meets the observed facts in a way quite impossible to a wave theory.

There are, then, undoubted facts in modern physics which simply cannot be reconciled with classical theories, and another region in which quantum ideas have been applied with brilliant success is that of spectroscopy. The facts of radio-activity lead to the postulation of a nuclear atom, which in its simplest (and now obsolete) form may be conceived as a nucleus made up of $(x + z)$ protons or positive electrical charges and x electrons. The nucleus thus has a positive charge ze, where e is the electronic (or protonic) charge, and electrical neutrality is assured by assuming that z electrons circulate, satellite fashion, in orbits around the

nucleus. The protons, a proton having 1 840 times the mass of an electron, supply the mass of the atom; z, the number of electrons in the satellite system, is the *atomic number*. The chemical properties of the atom are determined by the atomic number.

Consider now the simplest of all atoms, the hydrogen atom, which may be conceived as made up of one proton with a satellite electron. As far as classical dynamics is concerned any radius of the orbit is possible, and inasmuch as, on classical theories, a revolving electrical charge radiates energy we should expect the spectrum of hydrogen to be a continuous spectrum and the revolving electron as it loses energy gradually to spiral in towards the nucleus and finally to collapse therein. Once again classical theory fails and again we have to introduce quantizing motions. Bohr in 1913 assumed *first*, that only certain definite discrete stable states (orbits) were possible; *second*, that electrons in these orbits did not radiate; *third*, that when a hydrogen atom is excited say by impact with a photon or another atom, the electron moves from one orbit to another and in doing so radiates or absorbs quanta of energy equal to the difference between the energy states of the two orbits; *fourth*, that the angular momentum is quantized,* that is it is restricted to a number of discrete values the magnitude of the value in the N^{th} orbit being $(Nh/2\pi)$; N is termed a *quantum number*. This may seem to be an extraordinarily arbitrary proceeding, but it works, and the application of a little simple algebra results in an equation which represents the frequencies of the lines in the hydrogen spectrum with a remarkably high degree of accuracy. If we extend these notions to elliptic orbits with the nucleus in one focus of the ellipse, we have to deal with a varying radius vector and hence with varying radial momentum which has also to be quantized in a special manner. Two quantum numbers, therefore, are necessary—the so-called *azimuthal quantum* number (k) which quantizes the angular momentum as before, and what is called the

* The moment, or importance of a force in producing rotation is the product of the force into its distance from the axis of rotation. Momentum (mass × velocity or mv) may have a moment defined in exactly the same way and angular momentum is simply another term for moment of momentum.

radial quantum number (r), the sum of the two being set equal to the total quantum number N.

This simple concept of the planetary atom, remarkably successful though it has been in elucidating certain properties of single-electron systems such as that of the hydrogen atom, singly-ionized helium (that is, a helium atom which has lost a satellite electron), doubly-ionized lithium, and so forth is quite inadequate to cope with more complex systems. There are, however, fairly obvious extensions of the concept which may be made on empirical lines—extensions which result in what may be termed a *vector model* of the atom, in which we visualize the possibility that electrons and nucleus may *spin*, each about its own axis. There now arise many possibilities of that restriction of physical quantities to selected values which we have called *quantization*, and of the appearance of corresponding quantum numbers, especially if the electron be in a magnetic field strong enough to influence appreciably its spin and its orbital motion. Briefly, the quantum numbers which result are—

(1) A total quantum number (N).

(2) An orbital quantum number (l) which quantizes the orbital angular momentum and may have values 0, 1, 2, . . . (N − 1) where N is the total quantum number. It has properties very similar to those of the azimuthal quantum number k of the simpler theory and is connected with it by the relation $l = k - 1$.

(3) A spin quantum number s which has the value $\frac{1}{2}$, and quantizes the angular momentum which the electron possesses due to its own spin.

(4) A magnetic spin quantum number m_s, which arises from the projection on to the magnetic axis of the electron's angular momentum due to its own spin and has the values $\pm \frac{1}{2}$.

(5) A magnetic orbital quantum number m_l, which arises from the projection of the electron's orbital angular momentum on to the magnetic axis; its values range from $+ l$ through zero to $- l$; $(2l + 1)$ values in all.

If we consider the distribution of these subsidiary quantum numbers between those electrons which have the same *total* quantum number, and make use of an exclusion principle laid down by Pauli, it is not difficult to arrive at a distribu-

tion of electrons within the atom which accords well with the facts of experiment. This principle asserts that *no two electrons in an atom may have all their quantum numbers identical.*

Consider then those electrons which have a total quantum number 1.* If we examine the properties of the quantum numbers (2), (4), and (5) we see that l must be zero, m_l must be zero, and the possible values of m_s are $+\frac{1}{2}$ and $-\frac{1}{2}$. In accordance with the exclusion principle the only possible distribution of these quantum numbers (including the total quantum number 1) is between *two* electrons having the respective numbers $(1, 0, 0, \frac{1}{2})$ and $(1, 0, 0, -\frac{1}{2})$. These two electrons, being each at the same energy level, are said to constitute a *shell.* If we now consider the electrons at an energy level corresponding to a total quantum number $N = 2$, we see that l may be 0 or 1, m_l may be $+1$, 0 or -1, and m_s may be $+\frac{1}{2}$ or $-\frac{1}{2}$. In agreement with the exclusion principle we find that we can divide these numbers in *eight* different ways between electrons having the energy level corresponding to $N = 2$ and the second *complete* shell contains eight electrons (it may, of course, contain less). Similarly the third complete shell contains eighteen electrons, the fourth thirty-two, and so on.

Space will not permit a detailed discussion of the properties of the vector atom, and we must return to a consideration of the discrepancies between the waves and corpuscular theories of radiation. We have seen that, very early in the story of modern physics, there existed a striking dualism of outlook, some phenomena of radiation requiring a corpuscular, some a wave explanation. This dualism was further emphasized by the discovery of the Compton effect, which shows that when X-rays are scattered by impact with the lightly bound electrons in an atom, the radiation scattered at an acute angle has a smaller frequency than the frequency of the incident radiation—an explanation of this change being at once forthcoming if the problem is treated as a simple problem of elastic impact.† Suppose then that we

* In what follows, we need not consider the spin quantum number s ((3) in the list given), since this always has the value $\frac{1}{2}$.

† For if a light quantum hn communicates kinetic energy to an electron by impact the scattered quantum hn' will have less energy and hence n' will be less than n.

accept this dualism, and agree that radiation has a corpuscular aspect. Is it going too far to carry this dualism into our material concepts and to assert that matter may have a wave aspect? This notion was put forward by Louis de Broglie, who postulated that, with a particle having a momentum mv, there is associated a wave-length λ given by $\lambda = h/mv$. As radiation which shows the fundamental wave property of diffraction also exhibits corpuscular properties, so electrons which are conceived primarily as corpuscular may be expected to exhibit wave properties; which they do. If a beam of electrons is passed through thin foil, diffraction phenomena are observed which are perfectly consistent with the wave-lengths postulated by de Broglie. Moreover if, leaving the sub-atomic world, we deal with *molecular* rays of hydrogen or helium we may allow them to be reflected from a crystal surface and may observe diffraction phenomena consistent with the presence of a de Broglie wave-length of the right magnitude; *and we may collect the reflected waves as an ordinary gas.*

But all this merely emphasizes the dualism of the wave and corpuscle aspect of matter. This dualism is now disappearing under the analysis of the last few years—an analysis which has introduced the notion of probability into our estimates say of position. The method is essentially mathematical; we may describe the wave which accompanies a corpuscle by means of an equation which will contain an expression for the amplitude of the wave and the amplitude at any point gives us a measure of finding the electron at that point; if the amplitude vanishes anywhere, the probability of finding the electron at that point vanishes also. The concept of the electron as a definite entity at a definite point in space is replaced by a probability pattern which, very dense in a certain locality, rapidly thins as we move away from that locality. In fact if we fix our attention on the densest part of a given pattern, the probability of finding the electron at a distance greater than 10^{-13} centimetres from the densest part becomes vanishingly small. Most of us may be content to use the concept of an electron in almost our accustomed manner, realizing that it has become rather fuzzy at the edges.

And, despite the fact that it becomes possible to describe

a process in terms of particles or of waves it is important to stress the particle aspect of certain recently discovered phenomena—for the particle aspect provides the most easily comprehensible way of dealing with the matter.

Simple atomic theory apart, the story of the particles begins with the discovery of the electron, and of the rays of radium. Of these rays the α-rays are interpreted as fast-moving helium nuclei—helium atoms which have been stripped of their satellite electrons. These nuclei may be visualized for the moment as made up of four protons and two electrons, so that the nuclear mass is 4 and the nuclear charge 2—if the electronic charge is taken as unit. The β-rays are fast-moving electrons, and the γ-rays are X-rays of very short wave-length. The α-particle provides us conveniently with an atomic bullet which may be fired into material structures, and in the hands of Lord Rutherford the α-particle has been used with remarkable success to explore the complexities of atomic structure. The experimental technique, in its simplest form, consisted in observing the scintillations produced by the impact of the particles on a screen coated with zinc sulphide. Later an electrical method for detecting the ranges of the particles was developed in which the ionization produced by the passage of a particle through a gas is detected by means of an electrometer. But the most powerful weapon which the student of atomic ballistics possesses is the condensation chamber invented by C. T. R. Wilson. If a transparent vessel be filled with moist air and closed at one end by a movable piston, a sudden outward movement of the piston will expand the enclosed air and leave it in a supersaturated state. If now an α-particle be fired into the chamber its path is made visible by the condensation of vapour on the ions produced by the passage of the particle. By suitable mechanical devices it is possible to arrange that simultaneously the air in the chamber shall be suddenly expanded, the chamber submitted to α-particle bombardment, and the two cameras at right angles to each other exposed.

Electrons, α-particles and protons are electrical in origin; they may therefore be deflected by electrostatic fields. They move and so constitute an electric current; they may, therefore, be deflected by magnetic fields. Their charges and

masses may thus be deduced from their behaviour when subjected to the action of such fields. Recently special means have been devised for the generation of controlled fields of high potential which may be used to accelerate charged particles coming under their influence. It has been found possible in this way to produce high velocity protons which may be used in the bombardment of various elements. We can, in fact, now load, aim, and discharge our atomic rifle at will. If, for example, lithium be bombarded with high-velocity protons, it is found that α-particles are emitted, a process which may be explained in terms of a *nuclear equation*—

$$Li^7 + H^1 \rightarrow 2He^4 \text{ (or } 2\alpha^4).$$

(In words: the lithium nucleus of atomic mass-number 7 is bombarded by a proton of mass-number 1, and two α-particles, each of mass-number 4 result.)

With these advances in technique have come corresponding advances in discovery. Thus, the bombardment of a light element such as beryllium by α-particles results in the production of γ-rays together with a radiation which does not ionize the air through which it passes, but may be recognized by its effects on the nuclei which it itself bombards. We have to deal then with a massive *uncharged* particle, whose mass may be deduced from a consideration of the tracks made by the nuclei with which it collides. The mass of the particle is very nearly equal to that of the proton, and it has been called the *neutron*.

For a long time past it has been known that a radiation of high penetrating power exists in the atmosphere, a radiation which increases in intensity, that is in its power to discharge an electroscope, with increasing distance from the surface of the Earth. This is the so-called *cosmic radiation* which may be assumed to have its origin in interstellar space. Investigations on cosmic radiation, using the Wilson cloud chamber placed in a strong magnetic field, disclosed the fact that when cosmic radiation passed into such a chamber, tracks were produced, some curved in one direction, some curved in the opposite sense. This opposite curvature might be produced by a reversal of the sign of the charge or it might be due to the fact that the particle in

question was moving in a direction opposite to that of its fellows of opposite curvature. It was not difficult to rule out this latter possibility, and we are thus provided with another sub-atomic entity of mass equal to that of the electron and whose positive charge is equal in magnitude to the electronic charge. This is the *positron*.

Recent speculations concerning energy and momentum transformations in the nucleus have suggested the possibility of the existence of another particle, the *neutrino*, possessing no charge and, if Fermi be right, a negligible mass. Such a particle is not likely to be detected by direct experiment.

It may be well to mention here another particle which may be used in atomic bombardments, the *deuteron* or nucleus (H_1^2) of heavy hydrogen. Its properties will be dealt with in the physical chemistry section.

Obviously we have a considerable range of choice in our atomic building materials, and the supposition that atomic nuclei are composed of protons and electrons in suitable numbers may need modification. The α-particle, long described as being made up of four protons and two electrons may also be considered as composed of two protons and two neutrons, and there are good reasons for this supposition. But whether the neutron is an elementary particle and the proton may be written as neutron + positron or whether we are better justified in considering the neutron as proton + electron are matters which cannot be discussed here.

One of the most remarkable of the discoveries of recent years has been that of artificial radio-activity. Rutherford's fundamental discovery of 1919 was that transmutations may result from bombardment by α-particles. Thus, for example, the bombardment of nitrogen results in the transmutation described by the nuclear equation

$$N_7^{14} + He_2^4 \rightarrow O_8^{17} + H_1^1.$$

(In words: the nitrogen nucleus of atomic mass 14 and atomic number 7, when disintegrated by an α-particle yields the isotope of oxygen of atomic mass 17 and atomic number 8 together with a proton.)

Radio-active bodies on the other hand are bodies which break down spontaneously. We have various particles at

hand with which to effect transformations by bombardment of nuclei, and for the most part, the products resulting from such transmutations are stable. It might however happen that a product is produced which spontaneously disintegrates and we then have the phenomenon of artificial radio-activity.

The bombardment, for example, of aluminium with α-particles results in the emission of neutrons (the neutron n_0^1 being a particle whose mass number is unity and charge zero).

Hence we have

$$Al_{13}^{27} + He_2^4 \rightarrow P_{15}^{30} + n_0^1$$

the resulting product being an isotope of phosphorus.

But if the bombardment ceases we find that positrons are emitted, the positron (p) being a particle of negligible mass and unit positive charge. The isotope of phosphorus produced is in fact radio-active and spontaneously disintegrates in accordance with the nuclear equation

$$P_{15}^{30} \rightarrow Si_{14}^{30} + p,$$

the final product being an isotope of silicon.

Bombardment by protons, neutrons or deuterons may produce disintegration products which are unstable; the unstable products resulting from bombardments by α-particles or deuterons pass over into stable species, sometimes with the emission of positrons, sometimes with the emission of electrons; this latter species of decay—the β-active species—is often accompanied by γ-radiation, so that artificially produced radio-active substances behave in the manner characteristic of natural β-active substances. Neutron bombardment, when it produces radio-elements, produces elements which are β-active.

This section, which has already outrun its limits, has been concerned almost entirely with atomic physics. Advances are to be chronicled in almost every branch of physical science and a mere list of these advances would fill the space allotted to this section.

Progress in geophysical prospecting has been discussed in the section dealing with geology.

The flotation process for the separation of minerals is now

one of large-scale importance; a recent treatise, for example, gives costings for plant capable of dealing with 4 000 tons of ore daily. In the practice of this process the powdered ore is churned in water which contains some substance capable of producing a stable froth. The mineral which it is desired to concentrate must cling to the surface and so remain in the froth, the gangue sinking to the bottom, and a reagent must be added which ensures this. It is clear that some nice physical and physico-chemical problems are involved; in particular, a knowledge of contact angles is of great importance, and during the last year or two much attention has been given to the measurement of contact angles and to the application of the results to flotation processes.

Electron diffraction has been applied with success to certain problems in technical physics. The very small penetration of even the fastest electrons employed in this work makes them peculiarly suitable for the study of surface phenomena, and the method has been used in the study of surface structure, the poisoning of oxide-coated filaments, and in the investigation of various problems of lubrication.

In Sound, the acoustic design of halls is a matter which has only recently been thoroughly understood; problems of noise and its measurement have been actively investigated, from the psychological as well as the physical side. Odd little facts have emerged, e.g. that music is more disturbing to a student than an equal volume of typewriter noise. Horrors such as a photo-electric organ are impending.

The theory of the Brownian movement—the dartings to and fro of microscopic particles in suspension in a liquid, due to the irregular bombardment of the particles by the surrounding liquid molecules—has been further extended. On the practical side measurements have been made of the Brownian movement of delicately suspended balances—movements due, of course, not to mass-motion of air, or draughts, but to irregular molecular bombardment, and as a result of the determination of the amplitudes of such movements, a reasonably good value of Avogadro's number* has been deduced. Obviously if instruments become so

* The number of molecules in a gramme-molecule.

delicate that the Brownian motion of a galvanometer or a balance become appreciable, it is possible that Brownian motion may set a limit to the use of the instrument, and this question has recently received consideration.

There is no more fascinating story in the history of large-scale physics than that of the liquefaction of gases and of the approach to the absolute zero. Beginning with the liquefaction of chlorine by Faraday in 1823, and the investigation by Andrews of the critical state in 1863, the story is one long record of triumphs over difficulties which became steadily more formidable as the temperatures attained approached the absolute zero. Gases may be liquefied by the combined application of high pressures and low temperatures, each gas, as it is conquered, becoming itself an instrument for the production of still lower temperatures. Or we may make use of the fact that, when a gas is cooled by adiabatic expansion, the cooled gas may be used to cool still further the gas approaching the throttle at which expansion takes place. By one or other of these methods oxygen was liquefied in 1883, hydrogen in 1892, helium in 1908, and solid helium was produced in 1926.

There are other adiabatic processes which produce cooling besides the sudden expansion of a gas. A soap film is cooled if it is stretched suddenly, and certain magnetic substances, when suddenly demagnetized, are cooled. Ordinarily this last effect is very small, but it becomes appreciable at low temperatures. Crystals of a paramagnetic salt are surrounded by liquid helium boiling at 1·26° K. They are placed in a powerful magnetic field, and allowed to come into equilibrium with their surroundings. If the field is suddenly reduced, the rapid demagnetization produces a cooling effect which, with the salt potassium-chrome alum, results in the attainment of the incredibly low temperature of 0·03° K.

It would be possible to multiply indefinitely instances of remarkable recent advances in various branches of physical science, but in a review such as this it is only possible to choose a few topics of major interest on which to dilate. Even in the region of atomic physics, to which much space has been given, it has not been possible to discuss such important matters as crystal structure and the solid state,

band spectra, isotopes, the uncertainty principle, and the properties of heavy hydrogen and its compounds. Some of these are treated in the section of this review which deals with physical chemistry; others must perforce await a future review for their discussion.

XIV

PHYSICAL CHEMISTRY

By Professor Irvine Masson, D.Sc.

To this chapter has been committed a survey of all of chemical science which lies outside the special chemistry of carbon and outside that of live organisms. This is not to imply that organic chemistry and biochemistry have isolated themselves from the science; on the contrary, organic chemistry is a component of it, biochemistry an extension and a variety of applications of it; of the discoveries of organic chemistry many are as vital to general chemistry as others are to biochemistry; and there are no hedges between these fields. Nor are there hedges between chemistry and physics; they hold ground in common which is tilled by men from both sides of it.

In physical chemistry generally, a striking feature of late years is the prominence of quite complex mathematical weapons of analysis and prediction: weapons which often have had to be devised for the purpose by mathematicians of many nations, men whose co-operation has been as rich in results and as welcome to chemists as it must have been satisfying to themselves. This timely harnessing of very wide and partly *a priori* concepts to a science which has done what it has done rather by short-range induction *a posteriori* is, of course, not being accomplished without a little initial trouble. On one hand, younger men newly introduced to these wide concepts sometimes find it hard to submit to the severe discipline of slow experimental fact; and so some of the auxiliary work that is published uses experiments rather as eclectic illustrations of the mental hypothesis that is set forth than as absolute arbiters of it. On the other hand, the new theoretical tools of some very real (and many tentative) advances are not in everyone's power to handle, or even to appraise; and a self-respecting chemist could not feel quite honest if he merely used someone else's mathematical formula without really understanding how it expresses the concrete idea which he would like to test. Hence, if he

cannot gain that full understanding, he turns to inquiries on some less mathematical frontier: inquiries in which his knowledge is got at first hand from start to finish and in which, therefore, he can stand sponsor for his published conclusions *in saeculo saeculorum*.

The present bilingualism of chemistry may or may not be transient; in any case, as it is causing difficulties and segregations even among chemists, it is obvious that scanty justice to the subject can be done in the translations into ordinary English that are attempted here; and this introduction has been necessary partly to portray generally the existing state of chemistry, and partly so that the reader may himself correct the perspective of the foreshortened views of a few main topics, which will now be given.

Elements

There remain four elements which have yet to be decisively found, all of them odd-numbered in the Mendeléeff-Moseley sequence: *infra-iodine* (Number 87), *infra-caesium* (85), the missing rare-earth metal (61), and *masurium* (43). Of the last-named, nothing has been heard since its existence was indicated in 1925 by its X-ray spectrum, although its companion rhenium (atomic number 75, atomic weight 186) has been not merely authenticated but sedulously studied, and its compounds can now be bought over the chemical counter. But the era of looking for new elements, which used to be the most exciting search in chemistry, has now passed; for Moseley in 1914 put a limit to the contents of the only lucky-bag of them that Mendeléeff's classification—and Ramsay's additional group in it—had left unarranged.

The past five years have seen a wide enlargement of our knowledge of *chemical isotopes*, and even more fundamental new discoveries in the transmutation of chemical elements. Thanks mainly to Aston's mass-spectrograph, and in part to the application of mathematical physics to the details of optical spectra, almost every integer from 1 to 210 in the scale of atomic weights is now represented among the atoms of some seventy of the elements. On the average this would allot to each element atoms of three several masses; but this multiplicity is in fact very unequally spread, for it is only the even-numbered elements whose atoms tolerate

much variation in mass (weight). Of the odd-numbered elements, many have only one atomic mass apiece and the others rarely more than two; moreover they are less abundant in the world than the even-numbered. It seems, then, that the most normal atoms are those in which the nuclear electric charges (whose number in an atom is, of course, the Atomic Number) can be reckoned in pairs; why this is so is not yet surely known. Two isotopic atoms differ in mass by the mass of one, two, three or more neutrons, objects which weigh one unit apiece and have no other intrinsic property. But the number of positive electric charges in the nucleus is the same for both atoms, and since it is on that number that chemical properties depend, the two atoms are the same chemical element.

The subtleties of optical spectroscopy have afforded a new way to distinguish isotopes; especially when the atoms studied are so light that the few units of mass which differentiate the isotopes form a fairly large part of the whole mass of the atom. Oxygen, nitrogen, and carbon were each found in this way to contain minor isotopes, and the mass-spectrograph has confirmed the fact; and common hydrogen has likewise been added to the long list of isotopic mixtures. These four are all American discoveries. Since the main atom of hydrogen (weighing one unit) has about the same mass as a neutron, it follows that its isotope—the nuclear conflux of the two—is twice as heavy: a ratio not nearly attained among the isotopes of any other element. This great *relative* difference in mass makes *heavy hydrogen* more inert, physically, than *light hydrogen*; its atoms move more slowly. By means which use this fact, it can be isolated pure and in bulk, as no other element's isotope has yet been, although it forms only a very small proportion of natural hydrogen; and so "heavy" water, sulphuric acid, caustic soda, and others of its compounds are now commercial chemicals. It is given a name of its own, *deuterium* or *diplogen*, with the atomic symbol D; the molecule of heavy water is D_2O, that of heavy caustic soda NaOD, that of heavy benzene (*deuterobenzene*) C_6D_6, and so on. All over the world, innumerable details of its chemistry and physics are being studied. Meanwhile, let it be emphasized that it is still hydrogen in its chemical relationships with other

elements. Its compounds scarcely differ from those of light hydrogen except that they pack a little extra mass into a given space—in short, are heavier—because they carry as internal ballast some deadweight of neutrons. The same cause, making their molecules a little sluggish, probably explains the fact that pure D_2O upsets the delicately-balanced chemical responses in living organisms that are used to ordinary water, and kills the organism.

Another hydrogen isotope has been discovered, by less direct means; its atom weighs 3, as does the atom of a new isotope of helium. These are not at present obtainable in bulk, and are barely (if at all) detectable in the natural elements.

Transmutation of Elements

The simplest units of atomic structure which have now been studied as isolated objects in the flying débris of broken atoms include four which are new since 1930. Two of the four are the neutron, discovered mainly by Chadwick at Cambridge, and the positive electron or *positron*, discovered independently by Anderson in U.S.A. and by Blackett and Occhialini at Cambridge. These help to simplify the formulation of that complex which is the nucleus of the larger organism of the atom, the chief units of which may be tabulated—

Name	Electrical charge	Mass
Energy-quanta	0	Variable, fractional
Positron	+ 1	$\frac{1}{1800}$
Electron	− 1	$\frac{1}{1800}$
Neutron	0	1
Proton, hydrogen nucleus	+ 1	1
α-particle, helium nucleus	+ 2	4

(Whether any of these are or are not composed of pairs of the others cannot be discussed here.) To put the theoretical cart before the experimental horse, a chemical atom as a whole behaves as a place where these various entities become interchangeable. The atom is like a bank: if one of the entities is brought into it from outside, the bank pays out in return, either at once, or soon, or later on; but not

necessarily in the same coin as was paid in. The net result of an immediate exchange is that the bank's reserves (either of electric charges, or of mass, or of both) may be reduced, may remain unchanged, or may increase. And this new state of things may persist indefinitely, or else a new level of stability may be reached by the bank's paying out a series of further instalments.

More precisely: the not-too-swift encroachment of any of these entities upon the *outer* part of a whole chemical atom pays in energy-quanta, in exchange for which the atom pays out electrons. The integrity of the energy's vehicle is here untampered with, so that it goes on its way merely *minus* the energy it has left with the atom. This exchange in its early stages, before paying-out occurs, is *chemical activation*, for an atom at this stage is able to share its liability with others. If carried out fully, it is *ionization*. The exchanges in these outer parts of the atom are reversible, and no brokerage is charged; for the dislodged electrons can return and re-constitute the original atom, which then pays back the energy-quanta it had received as security—usually by emitting them as heat, or light, or X-rays. These outwork-exchanges (the subject of Bohr's theory) naturally defend the inner parts of an atom (Rutherford's special province) from easy invasion; it is upon their protection and their reversibility that the chemical individuality of elements depends.

But when, by a rare and extraordinarily forcible encounter, one or other of the six entities (or certain others) penetrates the Bohr outworks and breaks into the Rutherford nucleus, the exchanges which there go on are far more turbulent; and the bank, in paying out, now draws upon its store for any of the six forms of currency. (We are here merging many new discoveries, initiated at the Cavendish Laboratory at Cambridge and by Mme. I. Curie and F. Joliot in Paris and by Fermi in Italy.) If the entity now paid out by the impregnated nucleus is one which carries away fewer electrical charges than were paid in, the residue is no longer the same chemical element as it was before, but is an element in a higher Group of the Periodic System; if the entity paid out leaves the electrical charges unaltered by the transaction, the element remains the same as it had been; if the entity

carries off from the reserve in the nucleus more positive charges than were paid in, the product is an element in a lower Group than before. Along with this electrical balance sheet, a balance sheet in terms of mass is also struck; but a change in atomic mass *per se* does not affect chemical nature, and so the mass balance sheet only shows which isotopes are formed, the element's species being settled by the electrical balance sheet. In very many cases, the bombarded substance does not pay out at once, but goes on doing so after the bombardment, the paying-in, has ceased; the new material lasts long enough to be identified by chemical tests, and for its deferred emissions to be continuously measured. In other words, ordinary elements can be made radio-active.

Of all these facts, perhaps the most significant is that the building *up* of heavier atoms from lighter atoms is now being achieved in the laboratory: on a minute scale indeed, but the mechanisms used are such as go on without human intervention—as witness the "cosmic" rays—and natural super-chemistry has had longer to accomplish its syntheses than the few years in which we have begun to learn a little about them.

Chemical Structure and Chemical Action

What is a substance? In asking this we put aside as far too remote and quite premature the question "What is matter?"; and we pass the question, surveyed in the foregoing paragraphs, "What is an atom?" We accept atoms, all ninety-two of them from hydrogen to uranium; and instead of examining their inner structures, we now put two questions about their outward aggregations. In what ways are atoms assembled in groups, to form more complex units in the upward organization of matter, of bodies that can be handled? And how do these atomic clusters, whether large or small, manifold or simple, react chemically? That is to say, how do they break up again into atoms, or pool their atoms in new and larger clusters, or change the allegiance of their atoms over from one cluster to another? These have long been the two broad questions of orthodox chemistry; let us examine in turn, with almost equal brevity, the modern replies.

Volumes of physico-chemical work, in some directions

based on the Braggs' X-ray methods, in others governed by the recent work of Debye in Germany, and reinforced by widespread studies of great variety, now converge to show the make-up, flexibilities, and motions of molecules: their shapes—whether dumb-bell, chain-like, triangular, zigzag, ringed, stellate, pyramidal, or box-shaped; and their modes of assembly—whether at random as in a gas, or set in a kind of mobile ghostly semblance of a crystal as in water, or clumped by electrical couplings, or standing in upright regiments as in sticky films, or strung into nets as in jellies, or faggoted adherently but elastically together as in hair and other fibres, or lying slabwise as in scaly crystals, or built up, single atom by single atom, into a giant molecule like a crystal of carborundum.

What it is that ties atoms and molecules into these patterns grows increasingly plain. Nearly twenty years ago the established facts of chemical linkage, valency, were given an electronic basis by G. N. Lewis, of California, and his theory has since then been used by all chemists, among whom Britain has provided some of the leading exponents. Its theoretical mechanics, soon re-modelled to suit Bohr's discovery of the relations between atomic electrons and energy, are now being slowly translated in terms of the concepts of the new wave-mechanics; and this is not only stimulating much mathematical and physical thought, but is also beginning to elicit in return information (such, for instance, as Pauling's resonance-effect) which has led to fresh discoveries of fact. Chemists now recognize three agencies whereby molecules or parts of molecules combine; they are all electrical agencies, and the three have a common origin within the atom, but are responsible for separate external effects. There is the relatively feeble "van der Waals" cohesion which molecules, atoms, and ions all exert; it helps, for example, gases to liquefy. There is the strong electrical "Coulomb" attraction or repulsion, exerted between ions (electrified atoms or groups of atoms) of opposite or of like sign; it is an important factor in controlling the behaviour of salts, acids, and alkalies. And there is the linkage of chemical valency, which is not only closer and stronger than the other two, but is directional as they are not. It is set up between two atoms if their respective stockades of

electrons can be made to coalesce, to share a pair of stakes in common. This explanation of the valency-link was G. N. Lewis's original discovery; of its modern aspects, the one which we shall go on to notice is the *process* by which two atoms are led thus to interact. For it is a process with consequences so extraordinarily wide that it underlies and makes possible the material existence of this Earth and that of its inhabitants. On it also depend the lives of most of our greater industries: many of them are aware of the fact, and some have been at pains to foster the fundamental study of the matter, thus ensuring that they will know how to keep pace with novel demands in a world of unpredictable change, and shall so remain intrinsically stable.

It is familiar knowledge that some substances act chemically on each other, forming new substances, on being merely put together, provided that they are not exaggeratedly cold; whereas others need also to be heated, irradiated by light, or electrified, before this will happen. Again, a great number of reactions, whether hot or cold, go on only if a suitable foreign body—a solvent or a proper *catalyst*—is present. Moreover, a given substance can behave in one way in one such environment, and in a different way in another. All this seems very confusing; incidentally, it may give an inkling of the manifold practical experience that is needed in order to "bring off" reactions which look easy on paper. But mountains of studies on the speeds and heat effects of chemical reactions in liquids and in gases have lately been supplemented by studies of the behaviour of molecules at surfaces; and this correlation—initiated mainly by Langmuir, and much developed by half a dozen leaders and in scores of laboratories—has disclosed the unifying principle. This is, that an atom or a molecule remains chemically inert, even on collision, unless it has first been provided with an extra dose of energy. This extra energy must be enough to derange the outwork-electrons, so that when the strained atom meets another, their two electronic systems interlock; the two atoms thereafter remain, stably coupled by their shared electrons, as a compound molecule. An adequate intake of energy can likewise affect a whole compound molecule, making it vulnerable by some other. Or it may unlock the initial coupling, and send forth the severed parts;

such parts, if they meet some other molecule before they have had time to lose their share of the extra energy, can pass some of it on to this molecule and so start it into chemical activity in its turn. It will be seen that *activation* is a vital preliminary to chemical change; and all the diverse experimental arrangements for performing chemical reactions represent as many ways of putting the required stress into molecules or atoms that would otherwise remain inert. Activating a molecule is a little like cranking an engine.

Exactly how catalytic surfaces play their part in activating molecules and in promoting their intercourse would take too long to tell here. We may merely indicate its practical importance, by noticing that activation at solid surfaces is the controlling factor in the preparing of electric light bulbs and radio valves, in the making of synthetic ammonia and nitrates, in the making of sulphuric acid, in the purification of fats, in the hydrogenation of coal to oils and petrol, in the very burning of coal itself, of coke, and of gas; in the dyeing of fabrics; in the actions of living cells and tissues; and in scores of other processes, naturally as well as artificially vital to us all.

Finally, lest the smooth statements, of which an account such as this must be made, either convey an idea of easy achievement, or provoke doubts of the permanence of advances so rapid as these, let one more thing be said. It is no doubt applicable to other sciences besides chemistry to-day. Under the surface of these statements lies a multifarious intricacy of practical studies of such range, such minuteness, such severity of sceptical criticism, by so many people during so many years and in so many countries, that there seems to be left no room for personal fallibility, except in the finger-tip probing for the points next to be attacked. And all that can later happen to a body of knowledge gained in these ways is that it may be re-oriented *en bloc*, but not disintegrated.

XV

ORGANIC CHEMISTRY

By E. F. Armstrong, Ph.D., D.Sc., LL.D., F.R.S.

It is far from easy to make the lay public understand organic chemistry. There are so many carbon compounds, the composing atoms can be joined together in such a variety of ways to give a molecular architecture of amazing complexity, that the chemist has been forced to devise a kind of descriptive shorthand in the form of structural formulae which in themselves are models of lucidity and exactness, but are hardly to be explained to any other than the expert. It is one of the satisfactory things about these molecular formulae that they have withstood all the onslaughts of modern physical tests, including that by X-rays, so that whatever be their relation to the real molecule, the chemist at least knows that the deductions he draws from them can be substantiated in practice.

It is the broad aim of the organic chemist to determine the formula of every known substance and natural product, at first by analysis and degradation, and ultimately by synthesis. To this end he is concerned on the one hand with making and defining large numbers of new substances, and on the other with the study of reactions. The first aim has been largely realized: in the course of the work many thousands of compounds have been made, most of them being of little interest. A record of them is buried in the scientific journals or in *Beilstein's Dictionary*, sometimes termed "the graveyard of new compounds."

It is perhaps worth while to emphasize the enormous number of different substances of like number of carbon atoms which can exist owing to stereoisomerism. Whilst there are a mere seventy-five different substances containing five carbon atoms, classified as three hydrocarbons, eight alcohols, nine esters, twenty-one disubstituted paraffins with one radicle and thirty-one disubstituted paraffins with two radicles, there are 7 401 similarly classified containing ten carbon atoms, which is about the mean carbon

content of petrol, and it has been calculated that there can be over twelve million different substances containing twenty carbon atoms and oxygen, and over 148 million such when compounds with one or two substituents are included, all of which are saturated aliphatic open-chain compounds.

The achievements of the organic chemist during the last five years in the main consisted (*a*) in the elucidation of the exact molecular structure of many natural products, which the biochemist has taught are of outstanding interest, followed in many instances by their synthesis; (*b*) in the study of catalytic reactions whereby chemical compounds are formed in quantity with ease, which were previously obtained, if at all, with difficulty; and (*c*) in the better understanding of the reactions between organic substances in the light of modern theories of affinity. As a special phase of the activities of the organic chemist, there may be indicated the working out of methods for the manufacture in quantity at a low price of many organic substances for important industrial uses, which but a few years since were merely laboratory curiosities apparently of no practical value. It is in the course of this work that attention has been directed in particular to the synthesis of aliphatic or short open-chain molecules, using the familiar gases from coal or petroleum as raw materials, in contradistinction to those older syntheses of dyes and medicinal-chemicals which were based on the aromatic closed-chain raw materials like benzene, aniline, naphthalene and anthracene, derived from high-temperature coal tar.

In the following account it is not possible to do more than allude, without giving formulae, to certain groups of substances in which progress has been made during the five-year period, with an indication of the implications of the progress made.

It should be emphasized that progress in unravelling the more complex constitutions is necessarily slow and difficult. One worker puts forward a tentative suggestion based on his experiments, which is discussed by his fellow workers; this, if accepted, makes it possible for the next stage of the investigation to commence. The discussions held at British Association meetings are often fruitful on

these lines. At times a brilliant experimental discovery takes a whole section forward: viewed as a whole, the progress is nothing short of amazing. The last five years have seen the solution of the exact constitution of a long list of substances, particularly those of biochemical significance, and the unravelling of many additional tangles lies near at hand. The way is cleared for the study of the most complex colloid molecules and perhaps for an even more weighty task, the study of food and the proper understanding of food values—the definition of quality in chemical terms.

Carbohydrates

The marked progress here illustrates the general trend in the Science. The older formula of glucose, the type sugar, has been corrected and finally settled, thanks to the work of Haworth and the Birmingham School; this has enabled at last the structure of the disaccharides such as cane sugar and milk sugar, as well as other outstanding points of difficulty, to be definitely cleared up, leaving the way open to determine the structure of the complex carbohydrates such as starch and cellulose. Formulae have been produced for these which agree with the physical data, including those furnished by X-rays, and with the behaviour of hydrolysis. Generally speaking, the major problems in this field have been solved, though new ones have arisen. One of these is connected with ascorbic acid, a natural product present in Hungarian pepper, which has been proved to be a sugar derivative, its exact structure determined, and synthesis effected by methods which could be used for its commercial production. Special interest attaches to ascorbic acid because it has proved to be identical with Vitamin C.

Another new line relates to the specific carbohydrates in certain micro-organisms: here it has been possible to show how chemical changes in the nature of the groups that are present in the carbohydrates associated with both synthetic and natural antigens are reflected in the immunological properties of the antigens.

Fats

The long and patient analytical investigation of the fats, both animal of every possible origin from the highest to the

lowest in the zoological scale, and vegetable from all types of plants, concerning the number of carbons in the fatty acids, the nature of their saturation, and the form of the glycerides in which they are combined, has produced a mass of data from which it is at last possible to determine some correlation between fat and species. This has been attempted in particular by Hilditch, who has emphasized the parallelisms to be observed between fat types and evolution; for example, there is a marked simplification as we pass from the depôt fats of aquatic to those of land animals. Fats of aquatic origin are characterized by the presence in combination with glycerol of a considerable variety of acids, whereas in the ox fat there is twice as much saturated palmitic acid and no unsaturated C_{18}, C_{20} or C_{22} acids. In the higher plants it is clear that climatic temperature is the factor mainly operative in determining the relative saturation of seed fats. In many instances a quite distinct fatty acid is elaborated by individual plants; it is shown that the occurrence of these unusual features runs parallel with the groups into which morphologists have placed the plants.

Evolutionary development, though usually measured and described by morphological characteristics, must at bottom and internally be accompanied by chemical changes. These observations on the natural fats are a first step towards defining what these changes are. They exemplify the use of chemistry as a handmaiden of the other sciences, which must be one of its ultimate objects as soon as the constitution and inter-relationships of all natural substances have been established.

Plant Colours

The period has seen more or less finality in establishing the structure and even synthesizing the soluble red and blue plant pigments or anthocyanins, the work having been largely done by Robinson and his school at Oxford. These pigments are glycosides and it has been valuable to establish the nature of the sugars concerned and the point or points of their attachment to the complex aglucone. Apart from the chemical achievement, which is no mean one, the way has been prepared, thanks to the working out of simple methods of analysis, for the study of the factors governing the inheritance of these colours.

It is always the hope of the chemist to select a substance easily and quickly identifiable which is present in one parent only of a cross, and whose subsequent behaviour in successive generations can be followed.

A valuable summary of work of this kind recently prepared by Miss Scott-Moncrieff has shown that at least seventeen types of variation are involved in the pigmentation of our field and garden flowers and she has made much progress in summarizing the factors which influence pigmentation.

Another important group of plant colours in which great progress is to be recorded is that of the carotenoids which exist as hydrocarbons in the higher plants and as hydroxy-carotenes or xanthophylls in the lower plant, as, for example, fucoxanthin in brown algæ. A feature of the formulae assigned to carotene and lycopene is their symmetry about the middle of the molecule, one half being the mirror image of the other. In this they show an analogy with a triterpene, squalene present in fish livers.

The outstanding feature of carotene is, however, its identification as Provitamin A, which in the animal is converted into and accumulated as Vitamin A, a colourless substance with a molecule of half the length of carotene. The xanthophylls undergo no such transformation. A side issue of these fundamental discoveries of significance in nutrition, is the observation that the carotene content of butter runs parallel to the Vitamin A content. Pale winter butter contains much less vitamin than golden summer butter.

Incidentally, the progress with these pigments has been helped by and has in turn developed a valuable micro-chemical technique.

Great advances are also to be reported in what is the most important class of natural colours, namely the porphyrin group which includes chlorophyll and hæmin.

All these substances include a basic unit of symmetrical but very special structure, the nature of which is now clearly established. Minor points have still to be solved, but at long last we may claim to know the constitution of chlorophyll, which is a hundred years old, as a pigment extracted from green leaves, though it is only during the last thirty years that any progress in understanding its structure

has been made. Knowledge of the constitution may lead to some enlightenment as to the way in which chlorophyll works to build up substances in the living plant. The same remarks apply to the red colouring matter of the blood. In view of the very special ring structure of the porphyrins, more than a little interest attaches to a newly discovered blue pigment made in the laboratory, which contains a similar central sixteen-membered ring, in which four nitrogen residues (– N =) are substituted for four (– CH =) residues. This pigment is remarkably stable and is the finest and most widely useful blue yet known: its discovery and the elucidation of its constitution is a British chemical achievement of the first order.

Cardiac Aglucones

Progress has at long last been made in the elucidation of the structure of the cardiac poisons which, as glycosides from Digitalis and Strophanthus species, have valuable medicinal properties: this is largely due to the work of Jacobs in New York and Windaus in Germany. These substances, of which there are quite a number, have a highly complicated molecule, they are lactones and embody a system of four carbon rings: they are related to the sterols and to bile acid. The clearing up of their constitution is really a remarkable piece of work. It leads us on to study the toad poisons, e.g. bufotalin, which, though of animal origin, appear to be closely related.

Alkaloids

The formulae of the alkaloids are some of the most complicated known, particularly those of brucine and strychnine. Great advances are being made in their elucidation, the main features of their external skeleton being settled, but the formulae suggested for the internal structure still require further confirmatory work. In particular the ergot alkaloids, of which there are quite a number, are being investigated: it has been shown, for example, that the characteristic physiological effects of ergot are due to a new alkaloid, orgometrine, for which a structural formula has been suggested.

Arrow Poisons

There is a group of natural vegetable poisons which are extraordinarily poisonous to fish even in the minutest quantities and which are also of value as insecticides: they are used by the Malays as arrow poisons. The best known of these is rotenone, the constitution of which has been solved as the result of the efforts of the chemists of four nations. It is a complicated one, being built up of two benzene nuclei with various addenda and contains two oxide rings. The derris roots and other plants contain further toxic substances besides rotenone, but of close similarity in molecular formulae, suggesting a phytochemical relationship. The practical problem is to find the simplest structure which exhibits the poisonous properties, and so aids the science of pharmacology.

Another group of arrow poisons, to which it has been possible to assign structural formulae, are the curarê alkaloids.

Synthetic Rubber

The basic substance from which to effect a chemical synthesis is acetylene, which can be made by the action of water on calcium carbide. All sorts of products are made commercially from acetylene, for example aldehyde and acetic acid. One of the newest is vinylacetylene, a substance with a peculiar sweetish smell. This forms chloroprene when combined with hydrochloric acid, a compound having an analogous structure to isoprene, which is the unit particle of the complex natural rubber. In the hands of the chemists of the Du Pont Company, chloroprene has been polymerized to duprene, a rubber-like material far superior in every respect to natural rubber, though naturally more costly. This may be cited as one of the latest examples of the ability of the chemist to improve on Nature. Better dyes, better medicinals, better rubber, better resins, are only some of his achievements—the speed of their discovery is being accelerated as the knowledge of structure, of reaction technique, and of chemical engineering is increased.

Condensation and Polymerization

The organic chemist has sought to deal with crystalline

compounds of defined molecular size, but latterly he has extended his studies to much larger molecular aggregates, which he can never hope to reduce to single substances, the urge being largely given by the important properties of such substances which make them of high technical utility. The success of the first artificial resin—the phenol formaldehyde condensation product—has led to the wide study of *plastics*, as they are collectively termed, of all kinds, made from phenols, from urea, from aldehydes, from casein; and a very wide range of products, some of outstanding qualities, have been produced. Although the industry itself is to some extent empirical, a great deal of scientific work, both organic and physical, has gone to the selection of the materials and the study of the condensation reaction whereby such macromolecules are formed. They appear to grow like links in a chain by a special mechanism in which growth is rapid after initiation: it has been discovered, *inter alia*, that the properties of the polymers and condensation products may be altered to a remarkable extent by the addition of very minute quantities of other materials. As such macromolecules constitute cellulose, starch and the proteins, their investigation is fundamental.

Another form of polymerization is that which converts the smallest hydrocarbon molecules by heat treatment into larger molecules. This has the effect of turning the gases produced during the cracking of crude oil, back into a liquid product within the petrol range.

The scientific study of the processes of polymerization is attracting much attention. There is an hypothesis of stepwise addition, the first change being the formation of activated molecules or reactive radicles whereby the activation required is thermal, photochemical, or catalytic. Such high polymerides are peculiar in that they alone among organic molecules, display such mechanical properties as strength, elasticity, hardness. It is possible to distinguish between three main groups of molecular colloids differing in the lengths of the thread-like molecules. The technically most important substances have the largest molecules. It is important at this early stage to have some theoretical understanding of the manner of formation of these condensation products.

As illustrating the importance of structure, it is known that in chemical processes whereby cellulose is changed into various derivatives, and these again into products such as films, lacquers, or plastic masses, the delicate structure should be disturbed as little as possible.

XVI

SCIENCE AND INDUSTRY

By Sir Frank E. Smith, K.C.B., C.B.E., D.Sc., LL.D., Sec.R.S.

THE last five years have been a period of great importance in the development of industrial research in this country. In these years, almost for the first time in the history of British industry, important firms have set teams of research workers, including physicists, chemists, engineers, and, where necessary, biologists, to collaborate with the manufacturing and production sides of industry on the solution of a particular problem or on the development of a new product. This method has led to the evolution of creaseless cotton, to the pre-eminent position that this country has attained in the development of high-definition television, to the development on a commercial scale of the huge plant recently erected for the conversion of coal into oil by hydrogenation, to the recovery of the British dye industry, to the growth of the "plastic" industry, and to many other important industrial advances. Not only is British industry now realizing that research is essential as a basis for future progress, but it is appreciating more fully the help which the application of science can give in the solution of its day-to-day problems, in the gradual improvement of products, in the strengthening of weak links in the chain of production, in the control of raw material, whether of synthetic or natural origin, and in the general elimination of waste.

Those who had the future of organized industrial research at heart always felt some fear whether it could survive unharmed a period of severe economic depression. During the years of the economic crisis in this country, this fear was allayed. Some economies had to be made in the research organizations of industry as in other branches of industry, but these were carried through, in practically every case, with foresight and were only determined upon after anxious thought. In most cases, they took the form

of slowing down unpromising investigations and concentrating, sometimes with even greater vigour, upon researches which showed prospects of leading to definite and early results. Great care was also taken to keep intact skilled teams of research workers. The success of this policy is now being made manifest and the fact that it was followed in so many instances gives indisputable proof that our leaders of industry are becoming definitely "research-minded." Careful fostering of research in those difficult days was a definite part of Government policy and this afforded further evidence of the determination of the Government, which had received concrete expression in the days of the Great War in the formation of the Department of Scientific and Industrial Research, not to allow the link thus forged between science and industry to be weakened.

During the whole twenty years of its existence, the Department has not relaxed for a moment its efforts to encourage the application of science in industry. In its own establishments, it has continued to prosecute research vigorously on problems of national importance, and by its continued support of the industrial research associations, created largely as a result of its efforts, it has helped to bring the fruits of scientific knowledge within the reach of practically every manufacturing concern in the country.

During the last five years, many new buildings and many important pieces of equipment have been added to the National Physical Laboratory, which now covers an area of 50 acres and employs a staff of over 600. These have included a new physics building, together with a specially designed and fully equipped laboratory for acoustics research, besides new laboratories for photometric work. A second tank for testing ships' models has been added to the William Froude Laboratory, and, thanks to the generosity of Sir James Lithgow, special equipment has been provided for research on ships' propellers. Several new wind-tunnels, including what is probably the finest compressed air wind-tunnel in the world, have been erected in the Aerodynamics Department.

It is impossible to emphasize too strongly the value to industry of the Laboratory's work on the development and maintenance of the national standards for the measurement

of length, mass, and time, of the photometric or of the electrical standards, or of the work which has been carried out on the measurement of temperature and other physical quantities. It is now possible to make exact measurements of the yard and the metre in terms of the wave-length of the red radiation of cadmium light and thereby to determine a length to an accuracy of one part in a million. At first sight it may seem a far cry from measurements of such fineness to the demands of industry, yet the relationship is very close. In many of the mass-production processes of to-day the work is carried out in the factory to a tolerance of one ten-thousandth of an inch. To achieve this, the gauges employed in everyday use are periodically checked against sub-standards in the works. These sub-standards in turn must be correct to one hundred-thousandth of an inch. Hence, in order that the National Physical Laboratory may be able to calibrate these sub-standards, its own measurements of length must be exact to within a millionth of an inch.

To ensure that nuts and bolts shall be interchangeable it is necessary for the manufacturer to make screw threads to an accuracy of one two-thousandth of an inch. In making his stock, he uses taps and dies produced on a lathe, and in order that these lathes may do their work accurately, the National Physical Laboratory maintains a standard leading-screw, which is correct to within a few parts in a ten-millionth of an inch. The increased efficiency in electrical lamps and of electric lighting installations is directly related to the accuracy of the standards developed in the photometric department and to methods of measurements worked out there; while the accuracy of practically every electrical instrument produced in the country is ultimately dependent upon the electrical standards maintained at the Laboratory.

As illustrating the increased reliance which industry is placing on research, the figures for ships' hulls tested in the William Froude Laboratory are very striking. The number of designs examined increased from twenty-eight in 1932, to forty-five in 1933, and to sixty in 1934. This last number constituted a record for any year since the foundation of the Laboratory but, in 1935, this record was again exceeded, seventy-three ships being tested. Effective improvements were made as a result of the tests in sixty-four of the ships

tested last year. In thirteen cases, the improvement represents a saving of more than 10 per cent on the fuel consumption and in four cases, more than 20 per cent. In general, it may be said that the work of the Laboratory has improved the efficiency of ships by at least 20 per cent, and this improvement has given back to the shipping industry through a saving in fuel consumption a sum which, at a low estimate, must amount in the aggregate to at least £1 000 000 per annum.

Research work carried out in the Aerodynamics Department of the Laboratory has had a profound influence on British aircraft design, while the design of the machines which won the Schneider trophy for this country was based upon investigations carried out in its wind-tunnels. Recent researches carried out in the Department have contributed very greatly to a better understanding of the stability and control of aircraft and of such phenomena as "spinning," "stalling," and "buffeting" and should, therefore, contribute largely to increased safety in flying. Last year, tests in the compressed air wind-tunnel indicated that the speed of aeroplanes could be considerably increased by ensuring that the surfaces of the wings, etc., are as smooth as possible. It has been found that roughness corresponding to particles one four-thousandth of an inch in diameter may produce an increase of some 30 per cent of the resistance of a wing of a modern aeroplane travelling at 200 to 300 miles an hour, while even particles of a diameter of one-thousandth of an inch can produce an appreciable effect.

Many of the problems that puzzle the aeronautical engineer might be solved if it were possible to see the air flying over surfaces such as the wing of an aeroplane. Consequently much interest attaches to a new method which has been developed, by which a great deal of the fine detail in the air-flow over surfaces can be observed. It consists in the photography of the shadows cast by small spots of hot air moving with the current. These spots are produced by tiny electric sparks at suitable places in the air moving past a model. By using slow-motion cinematography the movements, which are too rapid to be followed by the unaided eye, can be slowed down to a speed at which every detail of the motion can be easily followed. Films now being made

show very clearly the nature of such phenomena as the stalling of wings, the effect of wing slots, and the reduction of resistance by streamlining, and are likely to have an important effect on future aircraft design.

In similar ways other departments of the Laboratory are making important contributions to industrial progress. Much work has been done on the development of light alloys for aircraft and for other purposes, and many investigations have been made on alloys suitable for use at the high temperatures employed or developed in modern machinery. In this connexion a special study has been made of the mysterious elongation called *creep*, which takes place at these temperatures and, to meet industrial demands, apparatus has been devised for measuring this quantity at rates as low as one-hundred millionth of an inch per inch per hour. By the use of the methods of electron diffraction, the part played in resisting corrosion by surface films, produced by the atmosphere on metals, is becoming better understood. The X-ray methods developed by Sir William Bragg for studying the crystal structure, invisible to the human eye, of metals and other materials have been applied to many industrial problems. In particular this work is leading to new knowledge of what happens when a piece of metal breaks. The connecting rod of an engine may run for years and then without warning fall into two parts, or a crane chain may be grossly overloaded and snap, but it has now been shown that in both cases the fracture has taken place for the same reason, namely because the same curious state of crystalline disintegration has been reached by a number of the minute crystals of which the metal is composed. The Radio Department has added materially to our knowledge of the propagation of electro-magnetic waves and has done much towards improving the accuracy of radio direction finders. In the Acoustics Laboratory the acute problem of the transmission of noise in buildings, and particularly in flats, has received special attention. It has been found that the transmission of sound through floors is of great importance not only in the obvious cases of impact noises but even in the case of a musical instrument played in an adjacent room, the disturbing sounds travelling through the legs of the instrument and the floor. A solution of the prob-

lem has been looked for in the provision of subsidiary "floating" floors insulated from the structural floors, and it is believed that a floor and ceiling combination of this kind can be designed and constructed sufficiently cheaply to allow its use in flats built for letting at low rentals.

A problem of the greatest national importance in this country is that presented by the use of coal. Coal is our greatest, indeed our only, raw material asset available in large quantities, and at the same time it is the fuel on which the majority of our industrial undertakings ultimately depend for their power supplies, whilst the winning of coal is also one of our greatest national industries. Scientific research, by improving the efficiency of power plants and generators, has increased the number of units of power which can now be generated by the burning of a ton of coal. On the other hand, it has shown how coal can be converted into more valuable or more convenient forms of fuel, and how by-products still more valuable can be obtained from it. It is a popular belief that the decrease in the home consumption of coal since 1914 has been due to the competition of oil, but this would seem to be only very partially true. For example, the total imports of oil for this country, including fuel oil and motor spirits, now amounts to about nine million tons per annum. This oil may be taken as equivalent in energy to about thirteen million tons of coal, and this amount of coal is less than the reduction in the annual demand for coal resulting from the improvements introduced since 1920 in the generation of electricity alone

A study of means for the better utilization of coal is the special task of the Department's Fuel Research Organization. In this work an increasingly important part is being played by the national survey of our coal resources, in which nine special laboratories, situated in the various coal-fields, are engaged in studying the different coal-seams as they occur underground. Samples cut from the whole height of these seams are analysed by standard methods. The amounts of phosphorus, and of chlorine—important on account of its effect on furnace linings—are also determined, together with the fusion temperature of the ash and other data. Where necessary, full-scale trials to test the suitability of particular

coals for carbonization, steam raising, or for use as pulverized fuel and the other processes are made in the commercial-scale test plants at the Fuel Research Station.

In the last five years colliery owners and industrialists generally have been making more and more use of the results of the survey. In some cases the market value of a seam as a whole has been increased by rejecting unsuspected bands of inferior coal, while, in others, neglected seams which were no longer being worked have been shown to have considerable value for certain processes. Again, commercial undertakings, long accustomed to a particular coal, a supply of which for various reasons was running short, have had their difficulties removed as a result of the survey being able to indicate where fresh supplies of a coal of similar character could be obtained. The survey is also helping the export trade by showing how the demands of the foreign importer can be met, and is, in general, increasing the high reputation of British coals.

In the course of the last five years, work at the Fuel Research Station on gas-making in horizontal retorts has shown that, by re-circulating the flue gases by comparatively simple means, the through-put of such retorts can often be largely increased, while in many cases an extra ten therms in the gas produced per ton of coal carbonized can be obtained by introducing steam in the retorts. Some seven million tons of coal are carbonized annually in horizontal retorts, and the results of the Fuel Research Station's work have had the effect of adding very considerably to the capital value of these plants. Pioneer research has been directed to the better understanding of the process of conversion of coal into oil by hydrogenation and, in addition, a semi-commercial plant dealing with 300 gallons of tar a day has also been recently erected for studying the conversion of tar obtained from low temperature carbonizing plants into oil. Supplies of tar are being obtained from the narrow-brick retorts designed and erected at the Station. These have been in use for three years for testing the suitability of various coal-seams for the production of low temperature fuel and show little sign of wear.

Important work has also been carried out on pulverized fuel. Pulverized fuel burners have been designed, suitable

for use in small plants and on board ships, which are capable of utilizing coals of low volatile content such as some of those from South Wales. Recently an ingenious device has been developed for feeding pulverized fuel evenly between two or more furnaces.

Yet another problem of national importance is that of building. The importance of good housing needs no stressing, while in addition buildings are a capital charge on every industry. The expenditure on new buildings of all kinds is about £150 000 000 per year, and the cost of repairs and maintenance probably about half this sum. At the Building Research Station considerable progress is being made in discovering a scientific basis for the traditional rule-of-thumb methods of the building craftsman. The technique which he uses has been developed as a result of long periods of trial and error, and has given excellent results in the past, but the introduction of new materials and the demand for speed in building have made the successful application of traditional technique impossible under modern conditions.

Investigations are being made not only on the materials used in traditional construction, such as stone, brick, and lime, but on the new materials of construction such as reinforced concrete, steel, and artificial stone. Easily applied methods for selecting Portland stone with good weathering properties have been worked out. It has also been shown that material prepared from waste spent shale from the Scottish shale oil distilleries can be used for making bricks and can be added to concrete to increase its resistance to chemical attack in place of certain natural clays imported from abroad. A method has also been developed for obtaining material suitable for use as aggregate in making light-weight concrete from the slag heaps of blast furnaces. In studying slates, it was found that a particular type of slate, of second-rate quality as a roofing material, expanded like a concertina when heated and that this material when broken up could also be used in making light-weight concrete. New knowledge is being obtained of how various salts get into bricks, and cause, by crystallizing out, the unsightly white patches on brickwork which are only too common. An excess of such salts, in particular of magnesium, has also been shown to be the cause of worse troubles such as

the actual disruption of bricks or the dislodgment of plaster work applied to them.

An important investigation on the design of steel-framed buildings carried out in co-operation with the British Steelwork Association is nearing completion under the Steel Structures Research Committee and has already enabled savings amounting to 20 per cent to be made in the cost of steel work for such buildings. It must be remembered, however, that a building must not only be a sound engineering job from the constructional standpoint, but must be comfortable, and safe as regards fire risks. In this connexion, the Building Research Station has recently carried out much important work on ventilating and heating problems and, in co-operation with the National Physical Laboratory, on the sound-proofness of buildings to which reference has already been made. In consultation with the Building Research Station the Fire Offices Committee of the Insurance Companies has also recently erected a fire-testing station which can be used for research on the fire-resistance of structures.

Another recent investigation carried out at the Building Research Station illustrates very clearly the way in which the technique developed by one section of the Department can help in the solution of the problems of another. In connexion with the design of concrete piles it was necessary to determine the value of the rapidly varying transient forces set up in the piles while they were being driven into the ground. This problem has been solved by the application of methods used for the control of the wave-lengths of wireless stations and for the study of atmospherics. Small quartz crystals were embedded in the piles which converted the mechanical forces set up in the piles by the blows of a hammer into electrical impulses which in turn were applied to the plates of a cathode-ray oscillograph.

Equally important with the work of the Department on building and fuel is that on the transport and storage of food. This work is carried out in the interests firstly of the home consumer, secondly of the home producer, and thirdly of the Empire producer. Not only is this research making possible a greater variety in diet, but it is also preventing waste. In this connexion, it should be remembered that the

cost of waste is always finally borne by the consumer, since the producer and distributor naturally take into account the risk of wastage losses in fixing the price the consumer is called upon to pay. Few results of research have been more energetically taken up by the interests concerned than the discovery that beef can be stored in a chilled condition for sixty to seventy days, a period enabling it to be carried in good condition to this country from the distant Dominions by enriching the air of the stores with carbon dioxide. The first shipment of chilled beef carried in gas storage was landed from New Zealand in 1933. Four thousand tons of chilled beef were carried from Australia and New Zealand in 1934 and, in 1935, the amount had already reached seventeen thousand tons. Last year, twelve ships were built for the Australasian trade and all had chambers specially constructed for the transport of beef in gas storage. Rapid strides have also been made in the application of carbon dioxide in the storage of British apples.* It has been found that at a suitable temperature and with 10 per cent of carbon dioxide in the atmosphere of a store and the oxygen lowered to 10 per cent, Bramley seedling apples, our most important cooking variety, can be kept in first-rate condition for the market for from six to twelve months. The first commercial gas store for apples was built in 1929, and to-day there are over forty in operation with a total storage capacity of about 400 000 bushels.

Gas storage is only in its infancy. Many varieties of home-grown apples require atmospheres of a different composition from that required for the Bramley seedling, and one by one appropriate conditions of storage are being determined. Already an atmosphere which will preserve the flavour of Cox's Orange Pippins has been found. The method of gas storage, moreover, is not restricted to apples alone, but is being applied successfully to pears, while promising results have also been found in the gas storage of tomatoes. So anxious are British growers to see rapid progress made in this work that, together with an important firm of refrigerating engineers, they have made the Department a valuable gift of cooling apparatus, which will enable research on gas storage to be carried out more quickly.

* Further details will be found in the section on "Botany."

Progress has been made in the study of the storage of almost every variety of perishable foodstuffs including fish, eggs, bacon, and poultry. In the case of herrings, a technique has been developed by which they can be made into first-class kippers months after they have been caught and the kippering process itself has been made the subject of scientific examination.

Another problem engaging the attention of the Department is concerned with the provision of more plentiful supplies of pure water for domestic and industrial consumption. Much important work has been done by the Water Pollution Research Organization of the Department on the purification of industrial effluents discharged into streams on which, after they have been treated, a large part of the population depends for its water supplies. It has been calculated that the effluents discharged from a beet sugar factory of average size have as much effect on polluting a stream as crude sewage from a population of 300 000 people, while the washing waters from dairies and factories making milk products are equivalent in polluting effect to sewage from a city of a million inhabitants. Satisfactory methods for dealing with both these industrial effluents have been found. In the course of a survey of the River Tees it was found that the serious effects of cyanides in effluents from coke ovens could be mitigated by treating these effluents with another trade effluent, namely, the waste pickle liquors resulting from cleansing iron and steel with hydrochloric acid. Work carried out for the Department's Water Pollution Research Board at the Chemical Research Laboratory has led to the preparation of good water-softening materials from British clays which have advantages over the imported products. This work has also revealed that certain synthetic resins have the property of removing metals from solution. A later development in this work is the discovery of another series of resins which remove acids. These two types of material, provided they can be produced economically, should find wide applications not only for water softening but also in the recovery of valuable products from industrial wastes. So complete is their action that by using two varieties of resin in series a sample of sea water becomes potable.

At the Chemical Research Laboratory also, further work on synthetic resins produced from coal tars has led to the discovery of a new and cheap wetting-out agent for use in the textile industries. In the same Laboratory pioneer work has been carried out on the use of high pressure in addition to heat to bring about chemical action. Alcohols, including ethyl alcohol, have been produced by the direct interaction of carbon monoxide and hydrogen under pressure. In addition, acetic acid, a substance of great industrial importance, has been obtained by the interaction of ethyl alcohol and carbon monoxide. Equipment has recently been constructed at the laboratory for experiments at pressures up to 3 000 atmospheres and temperatures of 200° C. Researches are also being carried out with the object of extending the employment of micro-organisms in industrial processes.

At the Forest Products Research Laboratory investigations are being made on the better utilization of timber and at the Road Research Laboratory work on the improvement of road materials and construction is on hand.

The work so far described is carried out in the public interest directly under the control of the Department under the supervision of its Boards and Committees. Much of it is done in close collaboration with trade associations and technical societies which, in many cases, make financial contributions to the cost of the work. As already stated, however, the aim of the Department is to bring scientific knowledge within the reach of every manufacturing industry in the country. The big industrial corporations are able to provide research organizations of their own, and to-day many industrial research establishments are costing anything up to £500 000 a year. The smaller concerns, however, are differently situated. A recent survey of over 128 000 factories in this country showed that less than 500 of them employed more than 1 000 workers, while over 117 000 factories employed less than 100 workers each. Obviously such firms cannot be expected to maintain efficient research establishments. To meet the case the Department in the early days of its existence, launched a scheme for creating in the industries autonomous co-operative research associations financed mainly by the industries themselves, but to which the State contributes in proportion to the amount

subscribed by industry. This experiment in the organization of research is unique to this country and, particularly in the last five years, has shown itself to be a pronounced success. Twenty such co-operative research associations are now actively functioning with grants from the Department. The research association movement has been found to appeal both to large and small firms—to the large firm because the associations carry out fundamental research on problems common to the whole industry or for which no individual firm has the requisite facilities; to the small firm because they provide a convenient means of keeping abreast of technical progress, and because of the skilled advice and assistance the staffs of the Associations are able to give in the solution of their problems. Well over £1 000 000 have been contributed by the State towards their maintenance, and the expenditure of this sum has attracted a total contribution from the industries themselves of nearly £2 000 000. It is never easy to express in terms of money value the results of research, but some concrete examples of the work of the research associations can be given. Annual savings of not less than £1 000 000 have accrued from work carried out by the Electrical Research Association, which cost £80 000 in all. The Cast Iron Research Association has produced a new type of blast furnace cupola which gives a saving of 1s. to 1s. 6d. on every ton of metal treated. There are sixty-one such furnaces now under construction, and the total saving when these are in full blast will be about £20 per hour. Possibly of more importance is the work of the Research Association on increasing the strength of cast iron. In 1928 it was possible for the purchaser to obtain cast iron with a tensile strength of about 12 tons per square inch. Nowadays it is practicable to produce on a commercial basis cast iron having a tensile strength approaching 30 tons per square inch, while further improvements have been made by the heat treatment of cast irons which are more sound, homogeneous, and uniform than ever before. The Iron and Steel Research Council, one of the more recent co-operative research bodies, has completed work which will mean a saving of about £392 000 per annum to the industry in the production of pig-iron and a saving in coal of not less than £1 340 000 a year in the production of steel.

The research association scheme covers not only the metal and electrical industries but such industries as leather, boots and shoes, flour milling, paint and varnish, printing, the automobile industry and many others. The textile research associations have carried out important work on the colour-fastness of fabrics to light, laundering, and perspiration, and, in particular, the Cotton Research Association has developed new machinery for opening and cleaning cotton which is likely to bring about revolutionary changes in these processes. As the result of a careful study of the Lancashire loom, effective remedies have been found for certain defects appearing in cloths of even the highest quality. The examination of the factors involved in mercerization and the dyeing qualities of mercerized material has proved of great practical value to the hosiery industry. In the case of wool the Woollen Industry Research Association has not only improved many machines used in the industry, but has introduced a new process by which white flannels can be prevented from becoming yellow upon repeated washing. Largely as a result of more precise knowledge of wool fibres obtained by X-ray methods a process of rendering wool unshrinkable has been evolved which is now nearing the stage of commercial exploitation. In the case of the Linen Research Association a successful series of experiments in the growing of pedigree flax have been carried out with the approval of His Late Majesty King George V on the royal estates at Sandringham. Year by year the area sown has been increased, and last year the crop was grown on 250 acres. The results indicate that this part of England should be very suitable for the production of pedigree flax seeds. During last year, the Chairman of the Research Association gave some remarkable figures regarding the increased yield per acre resulting from the use in Northern Ireland of pedigree flax seeds largely developed by the Association. He said that without these seeds the yield per acre would have been 30 stones less, so that pedigree seeds had increased the flax production of Irish farmers by about 120 000 stones and at current prices put over £60 000 into their pockets. However, the greatest hindrance to the development of the linen industry in the British Isles is the excessive amount of hand labour at present required,

and much of the work of the Association has been directed to a more complete mechanization of the industry.

Last year the Advisory Council of the Department, the Chairman of which is Lord Rutherford, was able to make an offer to the Research Associations of increased financial support from the Government, provided the Associations were prepared to extend their scale of working by obtaining increased contributions from industry. The response to this offer has been very encouraging and, generally speaking, has resulted in an assured increase of 30 per cent in the resources of the Research Associations as compared with the position two years ago. With only one exception, each of the Research Associations enjoys an income of over £10 000 a year, which is the minimum figure the Department regards as adequate if the position of an association serving even a small industry is to be considered secure. As illustration of the forward movement made by the Associations it may be stated that the total income of the Iron and Steel Industrial Research Council is now £31 000 a year as against £16 000 two years ago. The Electrical Research Association has increased its income in two years from £44 000 to £64 000 a year. In one year the Cotton Research Association increased its resources from £58 000 to £75 000 while the Leather Research Association has increased its income to £12 000 a year, representing an increase of 60 per cent in trade support. It is interesting to note that in many cases members of the Research Associations have shown a strong desire that a large portion of the increased resources of the Associations should be directed towards the development of long range researches on fundamental problems common to the industries as a whole.

Great as have been the advances in industrial research in the last few years, the Advisory Council of the Department in its reports has definitely stated that still more requires to be done if Great Britain is to hold its own industrially among the nations of the world. It is confidently hoped that the expansion of the research association movement will be continued, and that their scale of working will have doubled in the next few years. It is the progressive firms which engage in research, and it is right that these firms should reap the benefits, but, from the national point

of view, it is vitally important that the circle of scientifically minded firms should be enlarged. In all too many cases neither in the directorates nor among the technical and executive staffs is sufficient weight yet given, in British industry, to scientific attainment and experience. It is industry alone which can ensure the application of the results of research, and it is those firms which apply scientific methods to their day-to-day problems which will be capable of applying advances in knowledge to the best advantage, as they are made available by research.

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